Ballantine

NAVELEX 0967-LP-177-3010

INSTRUCTION MANUAL

MODEL 3028B DIGITAL MULTIMETER

Applicable To Units With Serial No. Prefix Thru 080-

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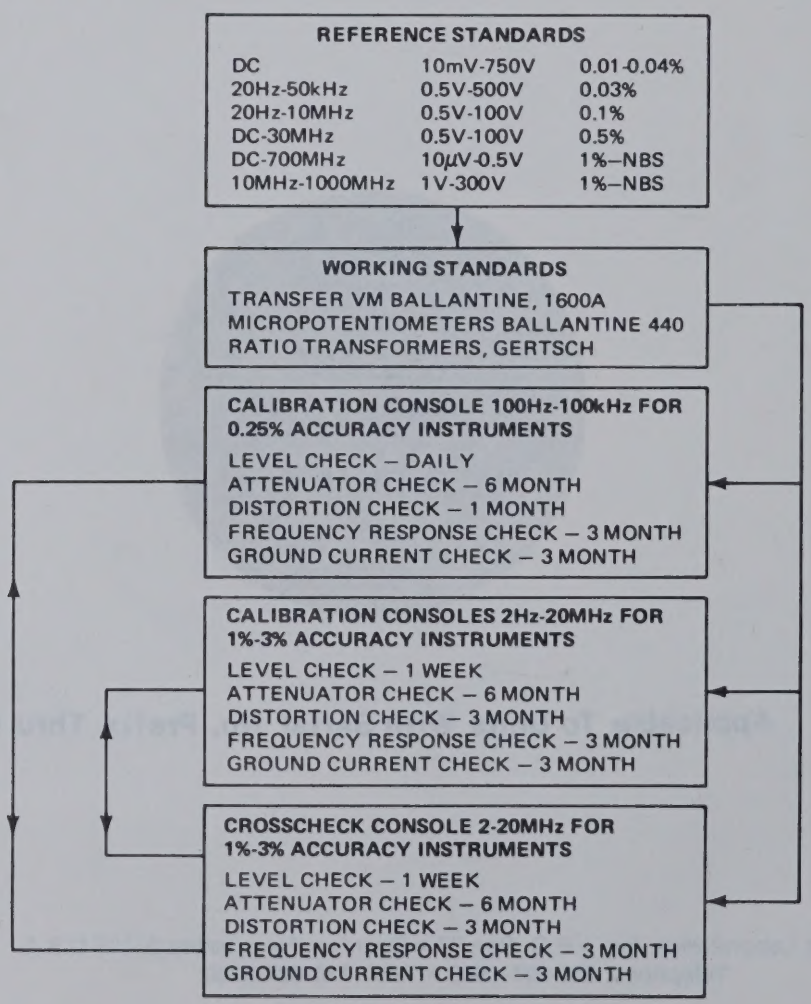

Ballantine's Quality Assurance program satisfied the requirements of MIL-I-45208

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Figure 1–1. Model 3028B, Digital Multimeter

SECTION 1
GENERAL INFORMATION

1–1. INTRODUCTION.

1–2. The Ballantine Model 3028B is a compact, lightweight, portable, digital multimeter (DMM). The instrument incorporates pushbutton selection of seven functions:

Volts	AC (rms responding)
Volts	DC
Amperes	AC (rms responding)
Amperes	DC
Ohms	LO (200 mV full scale)
Ohms	HI (2.0 V full scale)
Test	Display and battery charge

The 3028B features a bright orange, 0.43-inch, LED display of 3½ digits permitting plus or minus 1999 counts. Overrange is indicated by a blinking display. The decimal point is automatically positioned with range selection. Zero drift is prevented with auto-zero circuitry which is particularly useful for low-level and down-scale measurements. Overload protection is provided on all ranges by means of electronic limiters and without the use of fuses. A resettable circuit breaker is used for protecting the current ranges.

1–3. Pushbutton controls permit the selection of six ac and dc voltage ranges, six ac and dc current ranges, six LO ohms ranges, and six HI ohms ranges. The measurement capabilities of the 3028B cover thirty ranges from 100 microvolts to 1200 volts ac and dc, 10 nanoamperes to 1,999 amperes ac and dc, and 10 milliohms to 1,999 megohms LO ohms (<200 mV) and 1 ohm to 19.99 megohms HI ohms (<2.0 V). AC current and voltage measurement capability features rms response and extends from below 15 Hz to beyond 110 kHz. Automatic polarity indication with + or – sign is standard for all dc functions.

1–4. The Model 3028B is fully protected against accidental overvoltage to 1200 volts (dc plus ac rms) on any ac or dc voltage range and 285 volts (dc plus ac rms) on any ohms range will not damage the instrument. The current ranges are protected to 2 amperes by means of a reliable, fast-acting, resettable circuit breaker. Overload recovery is fast, enabling measurements to continue with no time loss.

1–5. Front-panel input connectors are convenient universal binding posts which permit use of banana plugs, captive wire leads, and lug-type connections. The three binding posts connect the volts/ohms, current, and common inputs. Binding post spacing is 3/4 inch (190 mm) to enable use of standard connector plugs, shielded connectors and adapters. The use of captive and shielded input connecting cables is a most desirable safety feature when making off-ground and hign-voltage measurements. A separate amperes input connector prevents damage to circuits being voltage tested by inadvertent selection of current measuring mode.

1–6. The COMMON input connector is isolated from earth ground and the ac power line mains can operate to ±1200 volts (dc plus peak ac) with reference to earth ground and to the front and rear panels of the DMM. The isolated COMMON input permits safe off-ground voltage and current measurements since it "floats" the instrument circuitry from earth ground.

1–7. A segment test for the three 7-segment LED digits is provided. Simply push both V and A pushbuttons to test all segments.

1–8. The instrument is enclosed in an attractive rugged case made of shock-resistant, flame-retardant plastic. The case is lined with a heavy conductive metallic coating which provides radio interference shielding. The 3028B is small and light enough to be easily carried. Quality components and reliable design techniques are used throughout to assure high reliability and low power consumption. A reliability analysis using the criteria of MIL-HDBK-217 shows an expected Mean Time Between Failure (MTBF) of 18,650 hours at 25°C.

1–9. SPECIFICATIONS.*

DC VOLTAGE.

Range	Maximum Scale	Resolution
±20 mV	±19.99 mV	10 μV
±200 mV	±199.9 mV	100 μV
±2 V	±1.999 V	1 mV
±20 V	±19.99 V	10 mV
±200 V	±199.9 V	100 mV
±1200 V	±1200 V	1 V

Accuracy:
1 year; 15°C to 35°C; ±(0.1% of reading +1 LSD); on 20 mV range only ±(0.2% of reading + 3 LSD).
24 hours; ±(0.05% of reading + 1 LSD).

Normal Mode Rejection:
Greater than 60 dB at 60 Hz or 50 Hz

Common Mode Rejection (1 kΩ unbalance; COMMON driven):
Greater than 120 dB at dc and 60 Hz or 50 Hz.
Greater than 130 dB at dc and 50 Hz, 60 Hz with internal battery (Option 05).

Maximum Input Voltage: 1200 V (dc plus ac rms sinusoidal)

Input Resistance: 10 megohms on all ranges

*All specifications apply from 10% of full scale to full scale. Note that option 24 deletes 20 mV, 20 μA, and 20 Ω ranges, as well as ac rms response.

Temperature Coefficient:
−10°C to 15°C and 35°C to 55°C
±(0.01% of reading/°C, + 0.005% of Full Scale/°C)

Response Time: ½ second

AC VOLTAGE.

Range	Maximum Scale	Resolution
20 mV	19.99 mV	10 μV
200 mV	199.9 mV	100 μV
2 V	1.999 V	1 mV
20 V	19.99 V	10 mV
200 V	199.9 V	100 mV
1200 V	1200 V	1 V

Response: RMS responding

Accuracy (sine wave): 1 year, 15°C to 35°C

Percent of Reading — 400 Hz Reference

15 Hz	45 Hz	10 kHz	20 kHz	50 kHz	110 kHz
±(5%+3LSD)	±(0.5%+2LSD)	±(1%+2LSD)	±(2%+2LSD)	±(5%+3LSD)	

20 mV Range only from 5 mV to FS

45 Hz	10 kHz
±(2%+3%)	

Accuracy (complex waveform): For signals having harmonic distortion less than 10% with no single harmonic greater than 5%, add ±(1% of reading + 1 LSD) to sine-wave accuracy from 45 Hz to 10 kHz and ±(1% of reading + 3 LSD) from 15 Hz to 110 kHz.

Temperature Coefficient:
−10°C to 15°C and 35°C to 55°C.
±(0.01% of reading/°C + 0.005% of Full Scale/°C).

Input Impedance: 10 MΩ in parallel with less than 100 pF

Common Mode Rejection (1 kΩ unbalance; COMMON driven):
Greater than 120 dB at dc and 60 dB at 60 Hz or 50 Hz with line operation.
Greater than 130 dB at dc and 70 dB at 60 Hz or 50 Hz with internal battery (Option 05) operation.

DC Blocking Voltage (Normal Mode): 1200 volts dc max.

Maximum Input Voltage: 1200 V rms sinusoidal on all ranges. Not to exceed 10^8 Volt-Hz.

Response Time: 3 seconds; typically 1 second (within one range).

DC CURRENT.

Range	Max. Scale	Resolution	Input Resistance
±20 μA	±19.99 μA	10 nA	1000 Ω
±200 μA	±1999 μA	100 nA	1000 Ω
±2 mA	±1.999 mA	1 μA	100 Ω
±20 mA	±19.99 mA	10 μA	10.1 Ω
±200 mA	±199.9 mA	100 μA	1.15 Ω
±2000 mA	±1999 mA	1 mA	0.25 Ω

Accuracy:
1 year, 15°C to 35°C; ±(0.3% of reading + 1 LSD)
on 20 μA range only ±(0.5% of reading + 3 LSD)

Temperature Coefficient:
−10°C to 15°C and 35°C to 55°C
±(0.015% of reading/°C + 0.005% of Full Scale/°C)

Voltage Burden at Full Scale: 0.25 volt maximum on all ranges except 0.5 volt on the 2000 mA range.

Maximum Input: 2 amperes (dc plus ac rms) continuous. Protected by resettable circuit breaker and diode clamps. Limit of 15 A peak.

Response Time: ½ second (within one range).

AC CURRENT.

Range	Max. Scale	Resolution	Input Resistance
20 μA	19.99 μA	10 μA	1000 Ω
200 μA	199.9 μA	100 nA	1000 Ω
2 mA	1.999 mA	1 μA	100 Ω
20 mA	19.99 mA	10 μA	10.1 Ω
200 mA	199.9 mA	100 μA	1.15 Ω
2000 mA	1999 mA	1 mA	0.25 Ω

Response: RMS responding

Accuracy (sine wave): 1 year, 15°C to 35°C

Percent of Reading — 400 Hz Reference.

All Ranges Except 20 μA and 2000 mA

15 Hz	45 Hz	10 kHz	50 kHz	110 kHz
±(5%+4LSD)	±(1%+2LSD)	±(2.5%+2LSD)	±(5%+4LSD)	

2000 mA Range

15 Hz	45 Hz	3 kHz	10 kHz
±(5%+4LSD)	±(1%+2LSD)	±(5%+4LSD)	

20 μA Range from 5 μA to FS

45 Hz	3 kHz
±(3%+3%)	

Accuracy (complex waveform): For signals having harmonic distortion less than 10% with no single harmonic greater than 5%, add ±(1% of reading + 1 LSD) to sine-wave accuracy from 45 Hz to 10 kHz and ±(1% of reading + 3 LSD) from 15 Hz to 110 kHz.

Temperature Coefficient:
−10°C to 15°C and 35°C to 55°C
±(0.015% of reading/°C + 0.005% of Full Scale/°C)

Voltage Burden at Full Scale: 0.25 volt maximum on all ranges except 0.5 volt on the 2000 mA range.

Maximum Input: 2 amperes (dc plus ac rms). Protected by resettable circuit breaker and diode clamps to 15 A peak.

Response Time: 3 seconds (within one range)

RESISTANCE.

Mode	Range	Max. Scale	FS Volts	FS Amps.	Reso-lution
LOΩ	20Ω	19.99Ω	20 mV	1 mA	0.01 Ω
LOΩ	200	199.9 Ω	200 mV	1 mA	0.1 Ω
LOΩ	2 kΩ	1.999 kΩ	200 mV	100 μA	1 Ω
LOΩ	20 kΩ	19.99 kΩ	200 mV	10 μA	10 Ω
LOΩ	200 kΩ	199.9 kΩ	200 mV	1 μA	100 Ω
LOΩ	2000 kΩ	1999 kΩ	200 mV	100 pA	1 kΩ
HI Ω	2 kΩ	1.999 kΩ	2.0 V	1 mA	1 Ω
HI Ω	20 kΩ	19.99 kΩ	2.0 V	100 μA	10 Ω
HI Ω	200 kΩ	199.9 kΩ	2.0 V	10 μA	100 Ω
HI Ω	2000 kΩ	1999 kΩ	2.0 V	1 μA	1 kΩ
HI Ω	20 MΩ	19.99 MΩ	2.0 V	100 pA	10 kΩ

Accuracy:
1 year, 15°C to 35°C
All LOΩ ranges, except 2000 kΩ range, and all HIΩ ranges, except 20 MΩ range, ±(0.2% of reading + 1 LSD)
LOΩ 2000 kΩ range and HIΩ 20 MΩ range, ±(0.5% of reading + 1 LSD)
LO Ω 20 Ω range, ±(0.8% of reading + 3 LSD)

Temperature Coefficient:
–10°C to 15°C and 35°C to 50°C ±(0.015% of reading/°C + 0.005% of range/°C), except ±(0.02% of reading/°C + 0.005% FS/°C) on LOΩ 2000 kΩ and HIΩ 20 MΩ ranges.

Response Time:
All LOΩ ranges, except 2000 kΩ range, and all HIΩ ranges, except 20 MΩ range, ½ second.
LOΩ 2000 kΩ range and HIΩ 20 MΩ range, 4 seconds.

Maximum Input Voltage (All Ranges) Continuous:
LOΩ 20, 200 Ω, and 2k ranges. HIΩ 2k range.
285 volts (dc + ac rms sinusoidal)
Intermittent (10 seconds 20% duty factor), 500 volts (dc + ac peak)
All other ranges.
Protected by electronic circuits to 500 volts (dc + ac rms) and 40 mA peak.

ENVIRONMENTAL.

Temperature:
Operating: –10°C to +55°C
Storage: –54°C to +85°C with batteries to 55°C

Humidity:
0 to 90% R.H.
0 to 85% R.H. to 45°C
Usable 0 to 98% R.H. without condensation.
Meets requirements of MIL-T-28800, Class 3

Altitude:
Operating: 0 to 3 km (10,000 feet). Derated linearly above 1 km from rated voltages above 300 volts to half rating at 3 km.
Storage: 0 to 15 km (50,000 feet)

Shock and Vibration: Meets requirements of MIL-T-28800, Class 3, Style D.

Case: Flame-retardant, shock-resistant plastic with full internal metallized shielding and earth-grounded aluminum panels. Handle detents in 12 positions and serves as tilt stand. Meets the requirements of MIL-T-28800, Style D.

Safety: Meets Requirements of MIL-T-28800, Class 3, Style D.

EMI: Meets requirements of MIL-STD-461A for CS-01, CS-02, CS-06, RS-02, and RS-03 to 400 MHz at 1 V/meter.

GENERAL.

Display:
4 digits and ± polarity sign
7 segment, bright orange
LED 1.1 cm (0.43 inch) character height

Display Test: Three digit, seven-segment test when pushing both V and A pushbuttons.

Dimensions and Weights:
Height: 62.7 mm (2.47 in.)
Width: 208.3 mm (8.20 in.); with handle 240.3 mm (9.46 in.)
Depth: 229.1 mm (9.02 in.); with handle 301.5 mm (11.87 in.)
Weight: 1.2 kg (2 lb 7 ox)
With batteries 1.85 kg (4 lb 1 oz)
Shipping Weight: 2.94 kg (6.5 lb)

Power: 103 to 128 volts (120 volts nominal), 50 to 400 Hz, 5 watts. Complies with MIL-T-28800, Class 3 power requirements. With Option 06, choice of 100/120/220/240-volt operation is available.

Supplied Accessories:
1 Power Cable, 6½ feet, P/N 33100000A
1 Instruction Manual, P/N 90101015
1 Probe Test Lead, 4 feet, (red)
1 Probe Test Lead, 4 feet, (black) } P/N 85100620A

1–10. AVAILABLE ACCESSORIES.

1–11. Table 1–1 lists the accessories available for use with the 3028B.

1–12. OPTIONS.

1–13. Several options are available for the Model 3028B. These options are listed in Table 1–2. Desired options may be specified at time of purchase. Contact your Ballantine representative for additional options which may be available. Table 1–3 defines options incompatibility. Refer to Section 7 for specifications and operating information.

TABLE 1-1. ACCESSORIES

Model	Description
10800B	40 kV, HV DC Probe
1301B	10 kV, HV AC Probe
10850B	RF Probe, 100 kHz to 700 MHz
10851A	RF Probe, 1 GHZ; with 100:1 divider to 500V RMS, dual banana (10 M Ω load)
10860C	Current Probe, AC, Clamp-on to 1000A
10801C	Test Lead Kit, 2 test leads
10731A	Carrying Case, soft vinyl, with carry strap
606	Shunt, AC/DC, 20 Amps (0.01 Ω)
10751A	Front Panel Protective Cover
800-09	Rack Mount Kit, left or right (one instrument)
800-10	Rack Mount Kits, side-by-side (two instruments)
12616A	Adapter, Shielded, double banana to BNC female
12617A	Adapter, double banana to BNC female
5340A	Tee Adapter
12249D	Cable, BNC to BNC shielded cable, 4 feet
12250D	Cable, BNC to alligator clips, 4 feet
12251D	Cable, double banana to BNC, 4 feet
12252D	Cable, Shielded, double banana to test probe
-	Battery Replacement Kit P/N 89104221A
-	50 Ohm Termination P/N 31-10189-0A

1-14. INSTRUMENT AND MANUAL IDENTIFICATION.

1-15. These Ballantine instruments are identified by a two section serial number. The first three digits section of this number identify the configuration code. This code number appears on the front page of this manual and must coincide with the first three digits of the serial number of your instrument. Addendum sheets supplied with the manual will define technical corrections or differences between your instrument and the unit described in this manual. If applicable, backdating information is located at the end of this manual. This backdating information pertains to instruments with serial number prefixes listed on the title page of this manual.

TABLE 1-2. OPTIONS

Options	Description	Factory Installed	Field Installed
01	Parallel BCD Printer Output	Yes	No
05	Internal Rechargeable Battery Pack with charger. 16 hour charge, 5 hour operation.	Yes	Yes
06	Standard for choice of 100/120/220/-240 volt mains.	Yes	No
20	Analog Panel Meter in addition to digital display.	Yes	No
21	20 Ampere Current Range.	Yes	No
24	Deletes 20 mV dc and 20 Ω ranges; provides only 20 kHz ac average responding detector.	Yes	No
24H	Deletes 20 mV dc and 20 Ω ranges; provides 100 kHz ac average responding detector.	Yes	No
25	AC Power Line Filtering and Surge Voltage Supression.	Yes	Yes
39A	Complies with FAA Specification		

TABLE 1-2. OPTIONS - Cont'd

Options	Description	Factory Installed	Field Installed
MOD163	Includes options 05,20,24H, RF Detector Probe Model 10850B.	Yes	No
MOD164	Includes Options 05,20,24H, RF Detector Probe Model 10850B and DC High Voltage Probe Model 10800B.	Yes	No
MOD165	Includes options 05L,20,24 and 10731A Carrying Case.	Yes	No
MOD168	Includes options 05,20,24H, RF Detector Probe Model 10850B, RF Detector Probe Model 10851A, High Voltage DC Probe Model 10800B.	Yes	No
MOD169	Includes options 05,20,24H, RF Detector Probe Model 10850B, RF Detector Probe Model 10851A, High Voltage DC Probe Model 10800B, Tee Adapter Model 5340A and 50 ohm termination P/N 31-10189-0A.	Yes	No
MOD170	Includes options 05L,20,24H, Deluxe Test Lead Kit Model 10801C and Carrying Case Model 10732A.	Yes	No
MOD171	Includes options 05,20,24H, RF Detector Probe Model 10851A, Tee Adapter Model 5340A and 50 ohm termination P/N 31-10189-0A.	Yes	No

TABLE 1-3. OPTION INCOMPATIBILITY

Option	01	05	06	20	21	24	24H	25	39A
01	-	N	Y	Y	Y	Y	Y	Y	N
05	N	-	Y	Y	Y	Y	Y	Y	P
06	Y	Y	-	Y	Y	Y	Y	Y	Y
20	Y	Y	Y	-	N	Y	Y	Y	Y
21	Y	Y	Y	N	-	Y	Y	Y	N
24	Y	Y	Y	Y	Y	-	N	Y	N
24H	Y	Y	Y	Y	Y	N	-	Y	N
25	Y	Y	Y	Y	Y	Y	Y	-	Y
39A	N	P	Y	Y	N	N	N	Y	-

- = Not Applicable N = Not Compatible Y= Compatible P = Included

SECTION 2
INSTALLATION

2–1. INTRODUCTION.

2–2. This section contains information and instructions necessary for the installation and shipping of the instrument. Details are provided for initial inspection, power connection, grounding safety requirements, installation information, and repacking instructions for storage or shipment.

2–3. UNPACKING AND INITIAL INSPECTION.

2–4. Unpacking and initial inspection of the instrument requires only the normal precautions and procedures applicable to the handling of sensitive electronic equipment. The contents of all shipping containers should be checked for included accessories and certified against the packing slip to ascertain that the shipment is complete.

2–5. PERFORMANCE CHECKS.

2–6. This instrument was carefully inspected for mechanical and electrical performance before shipment from the factory. It should be free of physical defects and in perfect electrical order upon receipt. Check the instrument for possible damage incurred in transit and, if necessary, complete the performance checks outlined in paragraphs 5–7 through 5–30. If there is any indication of damage or improper operation, refer to the warranty included in this manual and notify your local Ballantine field engineering representative or the factory.

2–7. POWER REQUIREMENTS.

2–8. The instrument is normally supplied to operate from any ac source of 103 to 128 volts. With Option 06 installed, the tapped primary of the power transformer can be wired to operate from any one of the following ac sources: 86 to 108 volts (100 volts nominal), 103 to 130 volts (120 volts nominal), 196 to 245 volts (220 volts nominal), or 208 to 260 volts (240 volts nominal). All instruments operate over the power frequency range of 48 to 440 Hz. Always verify that the operating line voltage is the same as that specified on the rear panel.

CAUTION

Failure to wire the instrument to match the operating line voltage will damage the instrument and may void the warranty.

2–9. The instrument may also be operated from internal rechargeable nickel cadmium batteries (Options 05 and 39). For battery operation, the line cord is disconnected. Fully charged batteries will operate the instrument for approximately 5 hours. With the line cord connected, the batteries can be fully charged from the line voltage within 14 hours with the POWER switch set to the OFF position. DO NOT charge the batteries for more than 20 continuous hours or the life of the batteries may be shortened. Upon receipt of the instrument, or after extended storage, the batteries should be charged for at least 8 hours prior to use.

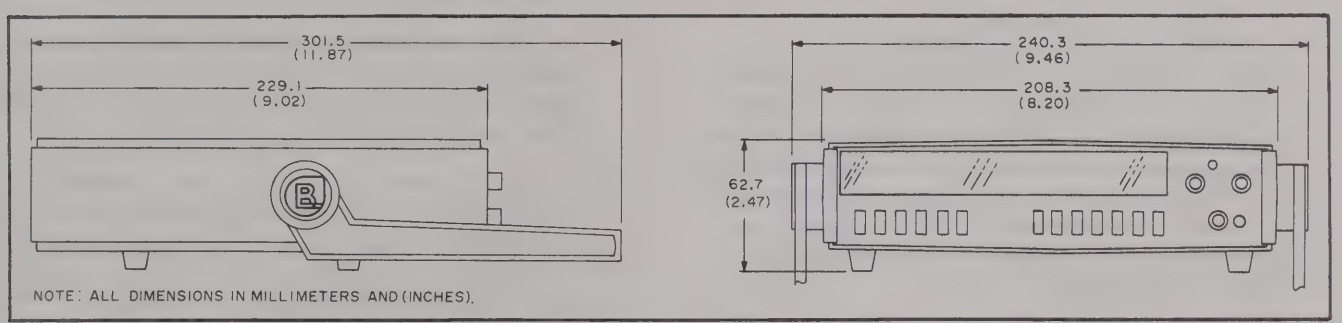


Figure 2–1. Model 3028B, Outline Dimensions

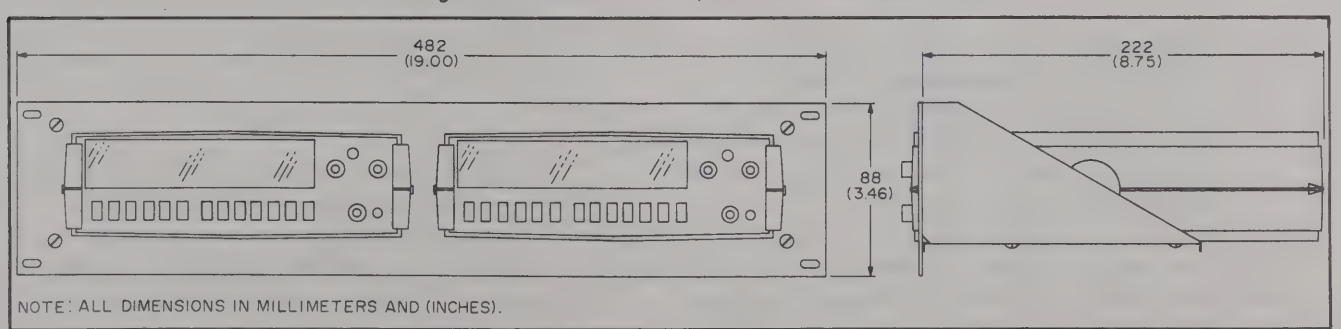


Figure 2–2. Rack Mount Kit, Outline Dimensions

CAUTION

When powering the instrument from extremely noisy ac power lines near pumps, elevators, or RFI emitters it is recommended that Option 25 be installed. This option provides power line transient suppression and additional filtering in applications which may otherwise damage the instrument.

2–10. GROUNDING REQUIREMENTS.

2–11. To insure the safety of operating personnel, the U.S. Occupational Safety and Health Act (OSHA) and good engineering practice require that the instrument panel and enclosure be "earth grounded." All Ballantine instruments are provided with a three-conductor power cable assembly which, when plugged into an appropriate power receptable, grounds the instrument. The offset pin on the male end of the power cable is the ground wire connection to the connector on the rear panel of the instrument.

2–12. To preserve the safety protection feature, when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green lead or terminal on the adapter to "earth ground."

2–13. When using the instrument on internal battery operation, there is no ground return through the power cord. Use caution to avoid electrical shock and consider connecting the instrument cabinet to earth ground through the rear-panel grounding lug or power receptable grounding pin.

2–14. INSTALLATION AND MOUNTING.

2–15. The instrument is fully solid state and dissipates minimal heat. No special cooling is required. However, the instrument should not be operated where the ambient temperature exceeds 55°C (131°F) or when condensation due to high relative humidity appears anywhere on the instrument. The instrument is shipped ready for use as a portable or bench instrument. Outline dimensions are shown in Figure 2–1.

Note

Before using the instrument, exercise each of the 13 pushbutton switches six or more times. This wiping action cleans switch contacts which may become noisy or intermittent during periods of storage or in contaminating environments.

2–16. The instrument case is provided with a carry handle which also serves as a tilt stand. To change the position of the handle, simply pull one side of the handle at a time outward from the case to disengage the detent mechanism; then, rotate the handle to the desired position, push the handle back toward the case and rotate slightly until it detents in place.

2–17. Rack mounting capability for the instrument is provided by a rack adapter panel. Three 19-inch EIA rack-mount configurations are available. See Figure 2–2 for outline drawings.

2–18. REPACKAGING FOR SHIPMENT.

2–19. If the instrument is to be repackaged for shipment, as a general guide, repackage the instrument as described in the following procedure and as shown in Figure 2–3. Use either the original packing material, if available, or material similar to that specified. Proceed as follows:

a. Place the instrument accessories, if any, in a plastic bag and seal the bag.

Note

It is recommended that NiCad batteries be removed from the instrument if extreme environments or storage in excess of twelve months is anticipated.

b. For long distance shipping only, use U.S. Government packaging method IIC and tape a two-unit bag of dessicant (MIL-D-3464) on the rear cover.

c. Place a piece of sturdy cardboard over the front panel for protection. Enclose the instrument in a plastic bag and seal the bag.

d. Wrap the bagged instrument and accessories in 1-inch thick, flexible, cellular plastic-film, cushioning material (PP-B-795) and place in a barrier bag (MIL-B-131). Extract the air from the bag and heat seal.

e. Place the wrapped instrument and accessories into a fiberboard box (PPP-B-636) of suitable size. Fill spaces with rubberized hair or cellular plastic cushioning material. Close box in accordance with container specifications. Seal with sturdy water-resistant tape or with metal straps.

f. Mark contained "FRAGILE," "HANDLE WITH CARE," or similar precautionary notice. Affix shipping labels as required or mark according to MIL-STD-129.

Note

If the instrument is to be shipped to Ballantine for calibration or repair, attach a tag to the instrument identifying the owner. Note the problem, the symptoms, and service or repair desired. Record the model and serial number of the instrument. Show the work authorization order as well as the date and method of shipment.

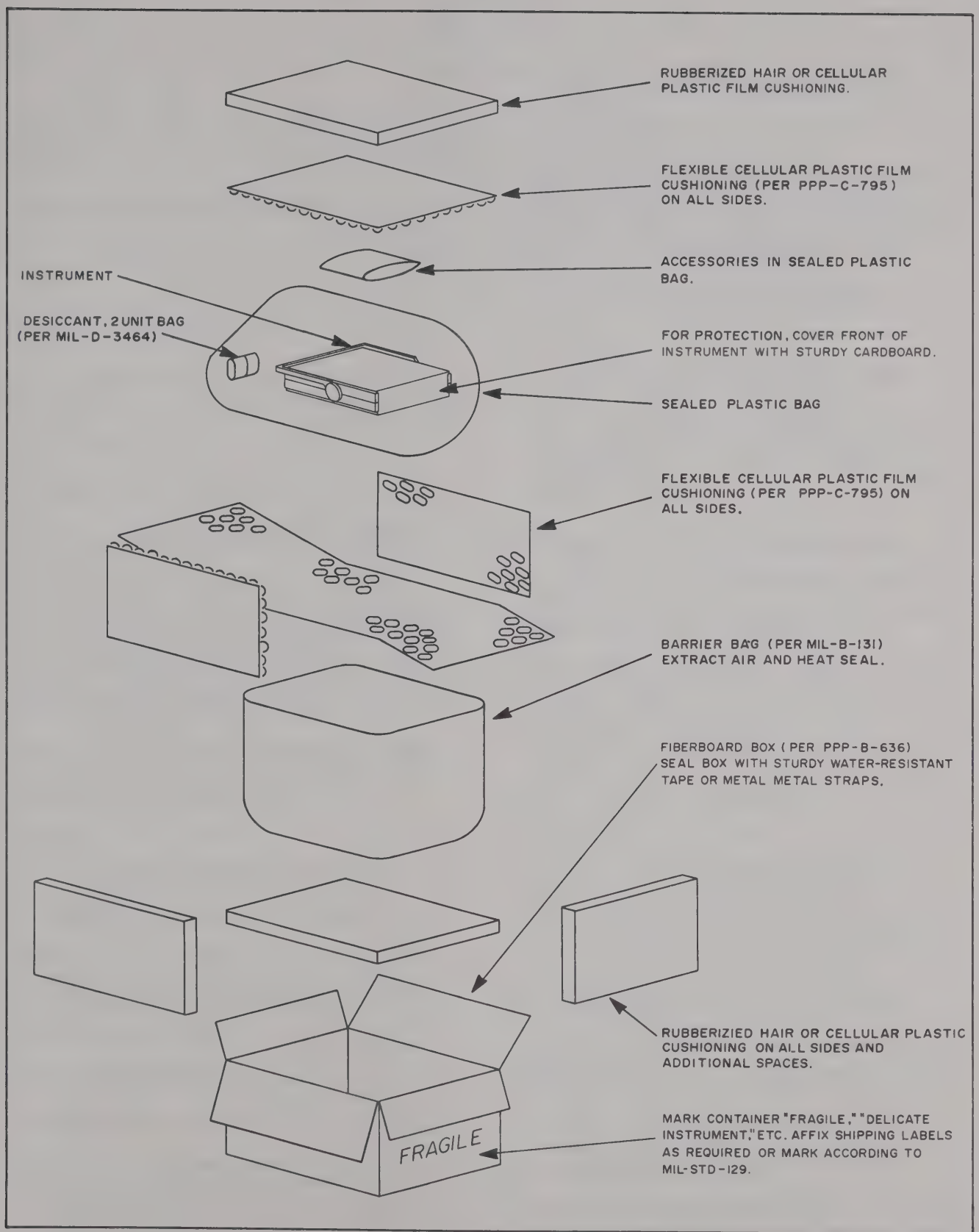


Figure 2–3. Model 3028B, Packing Diagram

NOTES

SECTION 3
OPERATION

3–1. INTRODUCTION.

3–2. This section contains instructions and information required for the operation of the instrument. Included are identification of controls, connectors, options and indicators.

3–3. CONTROLS, INDICATORS, AND CONNECTORS.

3–4. The controls, indicators, and connectors are identified in Figure 3–1 and Table 3–1.

3–5. POWER REQUIREMENTS (AC AND INTERNAL BATTERY).

3–6. See paragraphs 2–7 through 2–9. For grounding and safety earth connections see paragraphs 2–10 through 2–13. Apply ac power of the proper line voltage. Always check rear panel voltage label.

3–7. OPERATING INSTRUCTIONS.

3–8. Turn on power by pushing the POWER pushbutton in to the ON position. The digital display will light up to indicate POWER ON.

3–9. When using internal batteries (Options 05, etc.), check the battery charger condition by removing ac power and simultaneously pushing the 2000 k and 20 M pushbuttons. The display should read above 5 volts or the batteries must be fully charged for 16 hours by applying ac power and turning the power switch to OFF.

3–10. To check the display indicators, simultaneously push the V and A pushbuttons. All seven segments of the three right-hand numerals must light up.

Note

Additional instructions may be required when options are installed. These instructions are listed later in this section or in Section 7.

3–11. See Table 3–2 and select the desired range and function. Connect the test leads to the corresponding input connectors and observe precautions when measuring hazardous voltages.

3–12. DC MEASUREMENTS.

3–13. DC Voltage.

3–14. See Table 3–2 for dc voltage operation limits.

3–15. Select dc voltage.

a. Depress the V (S3) pushbutton.

b. Check that the AC/DC pushbutton (S2) is in (DC mode).

c. Depress the 1200 pushbutton (S11).

3–16. Connect the input signal to the COMMON and V–Ω input connectors. Select range by first depressing the 1200 (S11) pushbutton and then progressively increasing DMM sensitivity until the display shows three or four significant digits of information.

3–17. DC Voltage Measurement Precautions.

a. Do not exceed 1200 volts dc on any range.

b. Do not float the COMMON input binding post more than 1200 V peak above earth ground.

c. The input resistance of the 3028B is 10 megohms. Measurements from high-source resistances can cause additional measurement errors. This loading error may be calculated by:

$$\% \text{ loading error} = \frac{100 \times \text{Source Resistance}}{\text{Source Resistance} + 10 \text{ Megohms}}$$

For example, a source resistance of 100,000 ohms will cause a measurement error of 1% of reading.

d. An ac signal superimposed on the dc voltage to be measured may cause reading errors. Such unwanted ac signals are termed normal mode signals since they appear with the signal to be measured. The DMM has a normal mode rejection ratio (NMRR) greater than 60 dB (1000 to 1) at 60 Hz. As an example a 1-volt ac signal in common mode with a 100 mV dc input signal may cause ±1 millivolt of reading error.

e. When the DMM is floated above earth ground an unwanted signal may appear between earth ground and the COMMON input of the DMM. This common mode signal may cause measurement errors. The DMM rejects common mode signals with a rejection ratio (CMRR) of:

120 dB at dc	(1 million to 1)
100 dB to 60 Hz (sinewave)	(100,000 to 1)

This means that a 100-volt peak 60 Hz common mode signal will result in only 1 millivolt of measurement error.

CAUTION

Never exceed 1200 volts dc or ac peak common mode potential.

3–18. Overvoltage Indication. A flashing display indicates overvoltage (overload). Switch to the next higher range until a steady display appears.

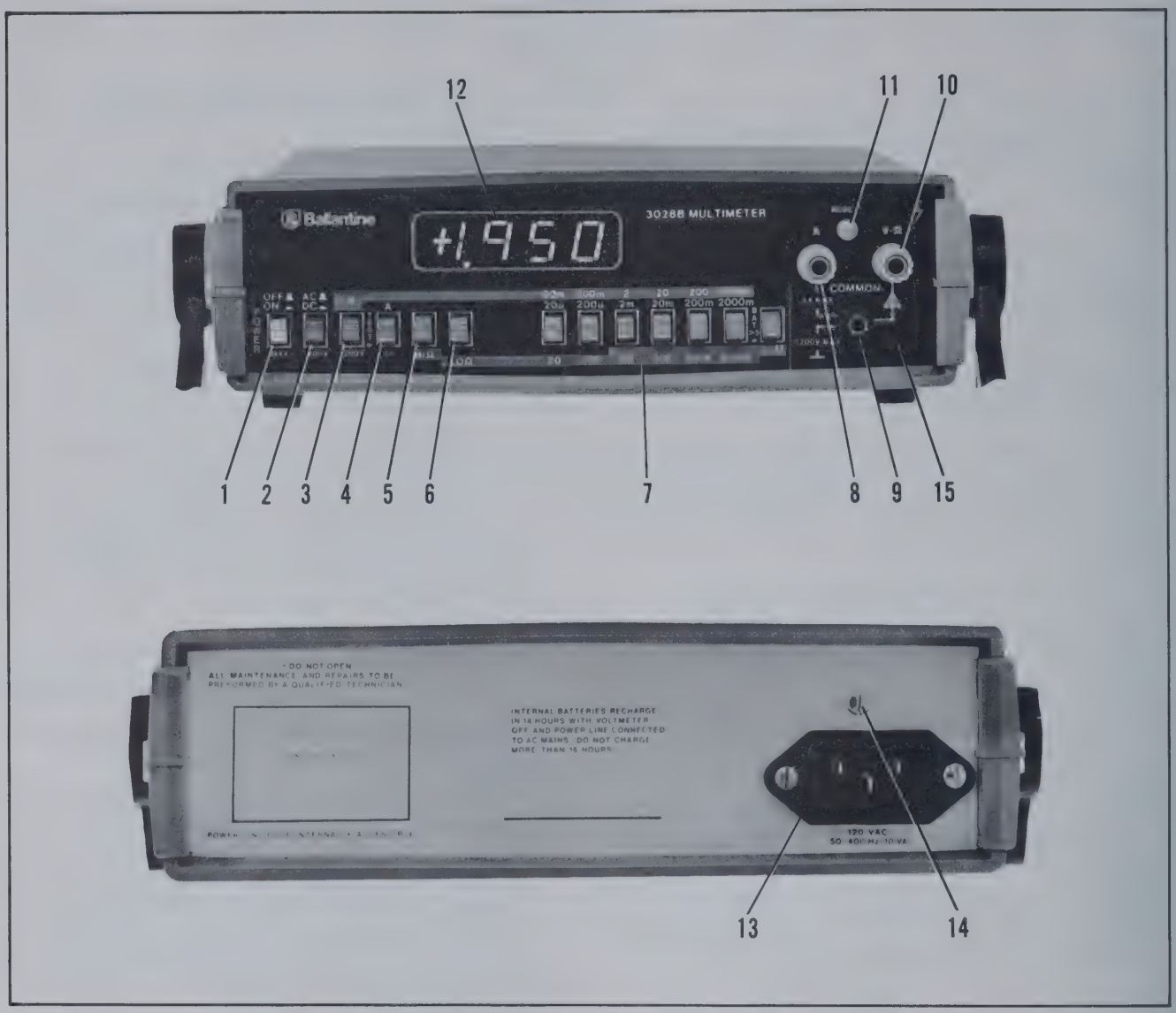


Figure 3–1. Model 3028B, Controls, Indicators, and Connectors

3–19. Overrange. The DMM may be used to 2999 counts on all dc ranges and modes up to the limitation of 1200 volts. A reading of 2000 represents full range and 1999 is considered full scale. The display will flash when full scale (1999) is exceeded. The DMM may be used to 2999 (reads 999 flashing) with the display flashing and with reduced accuracy.

3–20. Display zero is automatically adjusted. To check zero simply short the V–Ω to the COMMON input connectors with a short strap and the display will read zero plus or minus two counts on all ranges. The display will flash periodically but generally not more than ten times in ten seconds. The front panel zero screwdriver adjust may be used to set 000 on the 20 mV range when the input is shorted.

3–21. Automatic polarity is a feature of the instrument. Simply apply any dc voltage (negative to COMMON) and read the polarity sign on the display. Turnover error from plus to minus is held to within ±2 counts by the DMM circuitry.

3–22. DC Current.

3–23. See Table 3–2 for dc current operation limits.

3–24. Select dc current.

a. Depress the A (S4) pushbutton.

b. Check that the AC/DC pushbutton (S2) is in (DC Mode).

c. Depress the 1200 (S11) pushbutton.

3–25. Connect the input signal to the A and COMMON (–) input connector.

3–26. Select range by first depressing the 1200 (S11) push-button and then progressively increasing DMM sensitivity until the display shows 3 or 4 significant digits of information.

3–27. DC Current Measurement Precautions.

a. Do not exceed 2 amperes on any range. The circuit breaker will protect the A range on overloads above 2A. To RESET the circuit breaker, allow 10 seconds and push the button above the A binding post input connector.

WARNING

Do not exceed 15 amperes peak input.

b. Do not float the ammeter (dc current meter) COMMON input binding post more than 1200 volts peak above ground.

c. The dc A input is protected for overvoltage by clipping diodes which clamp at ±600 mV. The protective circuit breaker will trip whenever these diodes clamp and the resultant overload current exceeds 2 amperes.

TABLE 3–1. CONTROLS, INDICATORS, AND CONNECTORS

Index No.	Control, Indicator, Connector	Symbol No.	Function
1	POWER Switch	S1	ON/OFF switch, Charges battery in OFF position.
2	AC/DC Switch	S2	Selects ac or dc volts and amperes.
3	V Volts Switch	S3	Selects volts mode.
4	A Amperes Switch	S4	Selects A mode.
5	HIΩ Switch	S5	Selects high voltage (2.0V) ohms mode.
6	LOΩ Switch	S6	Selects LOΩ voltage (100 mV) ohms mode.
7	Range Switches	S7, S8, S9 S10, S11, S12, S70	Selects one of six voltage and current ranges and one of seven resistance ranges.
8	A Connector	J20	Binding post input connector for current mode.
9	COMMON	J30	Binding post input connector for voltage and resistance modes.
10	V–Ω Connector	J10	Binding post input connector for current mode.
11	RESET	CB10	Circuit breaker. Push to reset for current overloads >2A.
12	Digital Display	DS750-DS753	Digital readout consisting of 3 seven-segment numerics and 1 plus a polarity indicator.
13	AC Power Receptacle	J50	Power cable receptacle with ac power and "earth" ground.
14	Earth Ground Lug	–	Earth ground connection.
15	Zero Adjustment	R609	Screwdriver display 000 adjust for the 20 mV and 20 Ω ranges.

TABLE 3–2. MODEL 3028B OPERATIONAL LISTING

Selected Function	Selected Range	Maximum Input Overload Limits	Input Connections
V DC	20, 200 mV, 2, 20, 200, or 1200 V	1200 V dc or ac rms (sinusoidal)	V–Ω and COMMON
V AC	20, 200 mV, 2, 20, 200, or 1200 V	1200 V dc or ac rms (sinusoidal)	V–Ω and COMMON
A DC	20, 200 μA, 2, 20, 200, or 2000 A	2 A dc or ac rms. Circuit breaker protected to 15 A peak.	A and COMMON
A AC	20, 200 μA, 2, 20, 200, or 2000 A	2 A dc or ac rms. Circuit breaker protected to 15 A peak.	A and COMMON
HIΩ (> 1.8 V FS)	2 k, 20 k, 200 k, 2000 k, or 20 MΩ	285 V dc plus ac rms (sinusoidal) 500 V dc plus ac rms (sinusoidal)	V–Ω and COMMON
LOΩ (< 180 mV FS)	20, 200, 2 k 20 k, 200 k, or 2000 k	285 V dc plus ac rms (sinusoidal) 500 V dc plus ac rms (sinusoidal)	V–Ω and COMMON
Any	All Ranges	1200 V peak	Earth Ground (powerline) and COMMON

d. The shunts which meter current in the DMM vary with range. See the specification table in Section 1 for shunt resistance for each range. A measurement error will occur if the source resistance (R_s) is not at least 1000 times greater than the shunt resistance (R_r) of the DMM.

$$\% \text{ error} = \frac{100 \times R_r}{R_s + R_r}$$

For example, on the 2 A range where the shunt resistance (R_r) is 100 ohms, a source resistance (R_s) of 10,000 ohms will result in a dc A measuring error of 1% of reading.

e. An ac signal superimposed on the dc current to be measured may cause reading errors. Such unwanted ac signals are termed normal mode signals. The DMM has a normal mode rejection capability in the dc A mode but ac normal mode current signals should be avoided. When they add excessively to the rms current flowing through the shunt resistors, sufficient current may flow to trip the protective circuit breaker. The peak ac voltages superimposed on the shunt resistors should not exceed 500 millivolts peak-to-peak.

f. The DMM is almost always floated above earth ground when making current measurements. See paragraph 3–17(d) for a description of measurement errors caused by common mode signals. In typical use, the DMM will read ±10 counts of error when 100 volts peak of common mode signal is present. For common mode error calculations on the dc A ranges always use the most sensitive dc voltage range (20 mV), since the voltage developed across the DMM shunts is 20 millivolts full range.

g. The A to COMMON input connector resistance in the dc A mode is listed in the specifications. The connector-to-connector resistance is greater than the shunt resistance due to the internal connecting leads. Always consider the connector-to-connector voltage drop when making precision current measurements.

3–28. Overcurrent Indication. A flashing display indicates overload. Switch to the next higher range until a steady display appears.

CAUTION

Do not switch the current range switches when currents exceed 100 A. This will extend the life of the pushbutton switches.

3–29. The DMM may be used to 2999 counts (reads 999 flashing) on all dc A ranges to 1999 A (2 amperes). The display will flash when full scale (1999) is exceeded.

3–30. The display zero is automatically adjusted. To check zero in dc A mode short the A and COMMON input connectors with a short strap and the display will read 000 plus or minus three counts on all ranges.

3–31. Automatic polarity indication in dc A mode is a feature of this instrument. Simply apply any dc current (negative to COMMON) and read the polarity sign on the display. Turnover error is held to ±3 counts by the DMM circuitry.

3–32. Currents in excess of 1999 A may be measured using the Ballantine Model 606 Shunt. This shunt incorporates a 0.01-ohm resistor so that currents to ±20 amperes may be measured using the 200 mV dc range. The 3028B Option 21 is also available and it incorporates a 20-ampere current range.

3–33. AC MEASUREMENTS.

3–34. Response.

3–35. The 3028B Multimeter responds to the rms value of the ac input signal. A unique Ballantine computing ac to dc converter is incorporated in the instrument to permit accurate ac measurements even in the presence of total harmonic distortion of 10%. RMS response and calibration is used to provide a true measure of the power content (or heating value) of the input signal. Option 24 deletes ac response and provides only average response calibrated in rms of a sine wave.

3–36. The 3028B will provide accurate ac measurements of badly distorted signals. It will respond to the rms value of the input signal regardless of the phase of the input signal components. It is ideal for accurately measuring power line voltages and telephone test voltages, including ringing frequencies and two-tone signals. It is accurate even when total harmonic distortion exceeds 10%, provided no single harmonic exceeds 5%. The input signal should be symmetrical and periodic. See MIL-T-28800 para. 3.5.1.2.1(c) for standard power mains distortion.

When the input signal is a sine wave with sharp spikes or flattened peaks it is important to check the signal with an oscilloscope to be sure that the crest factor of the signal falls within the broad limits of 1.2 through 1.6 to one. It is usable over the range of 1 through 3 to one and beyond.

$$\text{Crest Factor} = \frac{\text{Signal Peak Volts}}{\text{Signal RMS Volts}}$$

Figure 3–2 shows the voltage relations of a sine wave. It indicates that the crest factor of a sine wave is 1.414.

The 3028B computing ac rms to dc converter has ample dynamic amplitude range for handling all specified crest factors. It is superior in all respects to peak or average responding detectors used in less sophisticated multimeters which will generally read the same as the 3028B on pure sine waves but which will read higher than the 3028B on ac input signals having crest factors <1.4 and lower than the 3028B for input signals with crest factors >1.4. The accuracy improvement of rms response can provide 4% better accuracy over average responding meters. For full true rms capability, including dc coupling to handle aperiodic and unsymmetrical signals with crest factors to 50, the Ballantine Models 3620A and 3630A are recommended.

3–37. AC Voltage Measurements.

3–38. See paragraph 1–9 for full operating specifications.

3–39. To Select AC Voltage.

a. Depress the V pushbutton and the 1200-volt range pushbutton.

b. Be sure the AC/DC pushbutton is out to select AC.

3–40. Measurement Precautions.

a. Do not exceed 1200 volts rms input on any range.

b. Do not exceed 1200 volts peak between earth ground and the COMMON connector.

c. Take care to minimize test lead capacitive loading of the circuit under test. Use test points which present the lowest possible source impedance. The V–Ω and COMMON input terminals of the multimeter are shunted by 100 pF and 10 megohms. Open test leads may add another 25 pF to 50 pF (or more if leads are twisted or run over a "ground plane").

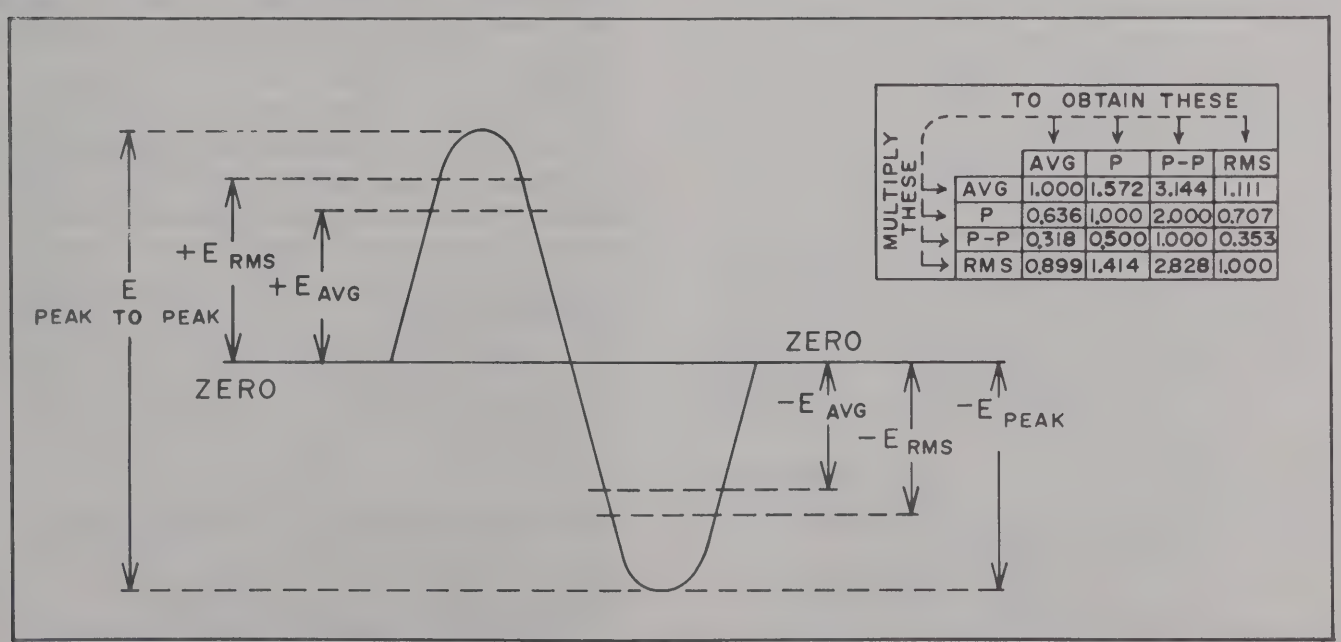


Figure 3–2. Average, RMS, and Peak Voltage Relationships of a Sine Wave

The loading factor of the shunt capacitance may be determined by the following relationship:

$$X_c \text{ (ohms)} = \frac{1}{2\pi Fc \text{ (Frequency) } F \text{ (Capacity)}}$$

Example for 100 pF shunt capacity at 10 kHz:

$$X_c = \frac{1}{6.28 \times 10{,}000 \times 100 \times 10^{-12}}$$

$$= \frac{1}{6.28 \times 10^{-6}} = 160{,}000\ \Omega \text{ of capacitive reactive loading.}$$

160,000 Ω is only 1.6% of the 10 MΩ shunt resistance but may present a considerable error when it loads an ac test point. In fact, to achieve less than 1% error in multimeter reading accuracy due to capacitive loading, the test point source impedance should be less than one one-hundredth of the combined capacitive loading impedance of the multimeter and test leads. In the foregoing example, the test point impedance must be less than 1600 Ω if the error is to be less than 1% or 160 Ω if less than 0.1%.

The loading effect becomes more important at higher frequencies but is present even at line frequency.

The total input impedance of the DMM may be calculated as follows:

$$Z \text{ input} = \frac{R_{in}}{\sqrt{1 + (2\pi F \times R_{in} \times C_{in})^2}}$$

Input Resistance = R_{in} = 10 Megohms = $10 \times 10^6\ \Omega$

Input Shunt Capacitance = C_{in} + C leads ≅ 150 pF

Frequency (in Hz) = F

As an example at 60 Hz

Z_{in} = 8.72 Megohms

Measurement error caused by a high source impedance (Z_s) may be calculated as follows:

$$\% \text{ measurement error} = 100 \times \frac{Z_s}{Z_{in} + Z_s}$$

As an example, the error of measurement at 60 Hz from a test point having 100,000 ohms source impedance (Z_s) using the DMM Z_{in} calculated above.

$$\% \text{ error} = 100 \times \frac{100{,}000}{8{,}720{,}000 + 100{,}000} = \frac{100{,}000}{8{,}820{,}000}$$

$$= 1.13\%$$

d. In addition, ac current (I) will flow in the leads causing additional measurement errors. In the above example, at 10 kHz, a 10-volt signal (E) will cause

$$I = \frac{E}{X_c} = \frac{10\ V}{160{,}000\ \Omega} = 62.5\ \mu A$$

to flow through the test leads and the input circuitry of the DMM.

e. The ac voltage or current to be measured may be "off ground." The multimeter must reject the off ground ac or dc "common mode" voltage. The rejection for common mode voltage is:

>120 dB at dc	(> 1 million to 1)
>60 dB at 60 Hz	(> 1000 to 1)

When making ac measurements, use the COMMON input connector as the "low potential" point to system ground (earth). This minimizes the common mode signal errors. Determine if the multimeter reads ac voltages when the test leads are shorted together and tied to the "high" side of the AC signal to be measured. If a reading of some magnitude is then displayed on the multimeter, try to minimize the amplitude of the voltage between case and COMMON. Always limit the common mode voltage to 1200 volts peak.

3–41. Overvoltage Indication. A flashing display indicates overvoltage (overload). Switch to the next higher range until a steady display appears.

3–42. Overrange. The DMM may be used to 2999 counts (reads 999 flashing) on the AC mode to the limits of 1200 volts rms sinusoidal (1680 volts peak) sinusoidal. 1200 represents full range and a reading of 1999 is considered full scale. The display will flash when full scale (1999) is exceeded.

3–43. Frequency range is usable from 15 Hz to beyond 110 kHz for both ac current and ac voltage measurements.

3–44. Display zero is automatically adjusted. To check zero simply short the V–Ω to COMMON input connectors with a direct buss wire strap. The display will read zero to 8 counts on all ac ranges. The additional counts beyond zero represent circuit noise seen by the wideband AC to DC converter. This noise adds to the signal as

$$V \text{ display} = \sqrt{(V \text{ input})^2 + (V \text{ noise})^2}$$

Noise contribution to measurement error therefore becomes insignificant for display readings above 0100 (5% of full scale). For lowest noise connect the COMMON to earth ground (lug on rear panel) to avoid common mode effects.

An example, 5 digits of DMM noise and 50 digits of signal give a display reading of

$$V \text{ display} = \sqrt{(50)^2 + (5)^2} = \sqrt{2{,}525} = 50.25$$

which will display as 50

3–45. AC Current.

3–46. See Table 3–2 for ac current operation limits.

3–47. To select ac current

a. Depress the A (S4) pushbutton.

b. Depress the AC/DC pushbutton (S2) out to select AC.

c. Depress the 2000 m (S11) pushbutton.

3–48. Connect the input signal to the A and COMMON (LO) input connectors.

3–49. Select range by first depressing the 2000 m (S11) pushbutton and then progressively increasing DMM sensitivity until the display shows 3 or 4 significant digits of information.

3–50. AC Current Measurement Precautions.

a. Do not exceed 2 amperes on any range. The circuit breaker will protect the A range on overloads above 2 A. To RESET the circuit breaker, allow 10 seconds and push the button above the A binding post input connector.

WARNING

Do not exceed 15 amperes peak input.

b. Do not float the ammeter (ac current meter) COMMON input binding post more than 1200 volts peak above ground.

c. The dc A input is protected for overvoltage by clipping diodes which clamp at ±600 mV. The protective circuit breaker will trip whenever these diodes clamp and the resultant overload current exceeds 2 amperes.

d. The shunt resistors which meter current in the DMM vary with range. See the specification table in Section 1 for shunt resistance for each range. A measurement error will occur if the source resistance (R_s) is not at least 1000 times greater than the shunt resistance (R_r) of the DMM.

$$\% \text{ error} = \frac{100 \times R_r}{R_s + R_r}$$

For example, on the 1 A range where the shunt resistance (R_r) is 100 ohms, a source resistance (R_s) of 10,000 ohms will result in an ac A measuring error of 1% of reading.

e. AC currents are often highly distorted yet the Ballantine 3028B improves accuracy since the instrument responds to the ac rms value of the input current. Refer to paragraphs 3–35 and 3–36 and the specifications in Section 1 for additional details.

f. The DMM is almost always floated above earth ground when making current measurements. See paragraph 3–17(d) for a description of measurement errors caused by common mode signals. In typical use, the DMM will read ±10 counts of error when 100 volts peak of common mode signal is present. For common mode error calculations on the ac A ranges always use the most sensitive ac voltage range (20 mV), since the voltage developed across the DMM shunts 20 millivolts full range.

g. The A to COMMON input connector resistance in the ac A mode is listed in the specifications. The connector-to-connector resistance is greater than the shunt resistance due to the internal connecting leads. Always consider the connector-to-connector voltage drop when making precision current measurements.

3–51. Overcurrent Indication. A flashing display indicates overload. Switch to the next higher range until a steady display appears.

CAUTION

Do not switch the current range switches when current exceeds 100 A. This will extend the life of the pushbutton switches.

3–52. The DMM may be used to 2999 counts (reads 999 flashing) on all ac A ranges to 1999 A (2 amperes). The display will flash when full scale (1999) is exceeded.

3–53. The display zero is automatically adjusted. To check zero in ac A mode short the A and COMMON input connectors with a short strap and the display will read 000 to 008. The residual counts are due to wideband ac circuit noise. See paragraph 3–44 for discussion of its minimal effects on ac measurement accuracy.

3–54. Currents in excess of 1999 A may be measured using the Ballantine Model 606 Shunt. This shunt incorporates a 0.01-ohm resistor so that currents to ±20 amperes may be measured using the 200 mV ac range. The 3028B Option 21 is also available and it incorporates a 20-ampere current range.

3–55. RESISTANCE MEASUREMENTS.

3–56. General. The 3028B measures resistance from 0.1 Ω to 20 MΩ. The display is read directly in ohms, kilohms (kΩ) or megohms (MΩ). The 3028B features both a LO ohms and a HI ohms resistance mode.

3–57. LO ohms may be used for resistance measurements which demand low voltage across and low power dissipation in the resistance to be measured. The LO ohms is advantageous when measuring in-circuit resistances in circuits using semiconductors. Diodes, transistors and other semiconductor junctions are not caused to conduct in the LO ohms mode since the voltage impressed across the unknown resistance is 20 mV at full range. See Table 3–2 for LO ohms operating specifications.

3–58. The HI ohms mode is used for checking higher resistances to 20 megohms and for testing semiconductor junctions. The voltage impressed across the unknown resistance is 2.0 V at full range. This is sufficient to test conduction of diodes and transistors as well as to minimize the effects of leakage. See Table 3–2 for HI ohms operating specifications.

3–59. To select LO ohms

a. Depress the LO Ω pushbutton (S6)

b. Depress the 200 range pushbutton (S7)

3–60. Connect the resistance to be measured across the V–Ω and COMMON input connectors.

3–61. Select range by first depressing the 200 pushbutton (S7) and then progressively increasing the resistance range until the display shows 3 or 4 significant digits of information.

3–62. LO Ohms Measurement Precautions.

a. Do not apply voltage to the input terminals when using LO ohms mode or the reading will be in error.

b. Short the input test leads before making a measurement. On the 20-ohm range, adjust front-panel ZERO screwdriver control (R609) for display zero. to compensate for lead resistance. On all other ranges note the zero offset due to test lead and internal resistance of the DMM (typically less than 0.4 ohm). Subtract this "measured zero" reading from the actual measurement to obtain the most precise resistance measurement.

Note

Always check ZERO adjust when using the 20-ohm range and readjust when using the 20 mV and 20 mA ranges.

c. Do not exceed 285 V rms (sinusoidal) to the input terminals on the 20 and 200 range or more than 500 V rms (sinusoidal) on other ranges to prevent overload damage.

CAUTION

Take care when making in-circuit resistance measurements which may have high voltages on capacitors or where power line voltage is present.

d. Avoid the LO ohms 2000 k range since its accuracy is affected by leakage in high humidity environments.

e. The LO ohms mode is not applicable to the 20 MΩ range and the display will flash if this range is inadvertently selected.

3–63. To Select HI Ohms

a. Depress the HI ohms pushbutton (S5).

b. Depress the 2 K range pushbutton (S8).

3–64. Connect the resistance to be measured across the V–Ω and COMMON input connectors.

3–65. Select range by first depressing the 2K pushbutton (S8) and then progressively increasing the resistance range until the display shows 3 or 4 digits of significant information.

Note

The 200 range (S7) is not operative in the HIΩ mode and the display will flash should this range be inadvertently selected.

3–66. HI Ohms Measurement Precautions.

a. Do not apply voltage to the input terminals when using HI ohms mode or the reading will be in error.

b. Short the input test leads before making a measurement. Note that zero offset due to test lead and internal resistance of the DMM (typically less than 0.4 ohm). Subtract this "measured zero" reading from the actual measurement to obtain the most precise resistance measurement.

c. Do not exceed 285 V rms (sinusoidal) to the input terminals on the 100 range or more than 500 V rms (sinusoidal) to prevent overload damage.

CAUTION

Take care when making in-circuit resistance measurements which may have high voltages on capacitors or where power line voltage is present.

3–67. Overrange Indication. A flashing display indicates too high resistance for the range selected. Switch to next higher range until a steady display appears.

3–68. The DMM may be used to 2999 counts (reads 999 flashing) on all ohms ranges to a limit of 2 megohms in LO ohms and 20 megohms in the HI ohms mode. The display will flash when full scale (1999) is exceeded.

3–69. The display zero is automatically adjusted. To check the display zero, connect the test leads to the V-Ω and COMMON input connectors and short them together. Note the reading which typically should be limited to .001 to .010 by keeping the test leads short and the resistance low. Note the "actual zero".and subtract this offset from the actual reading to obtain the most precise resistance measurements.

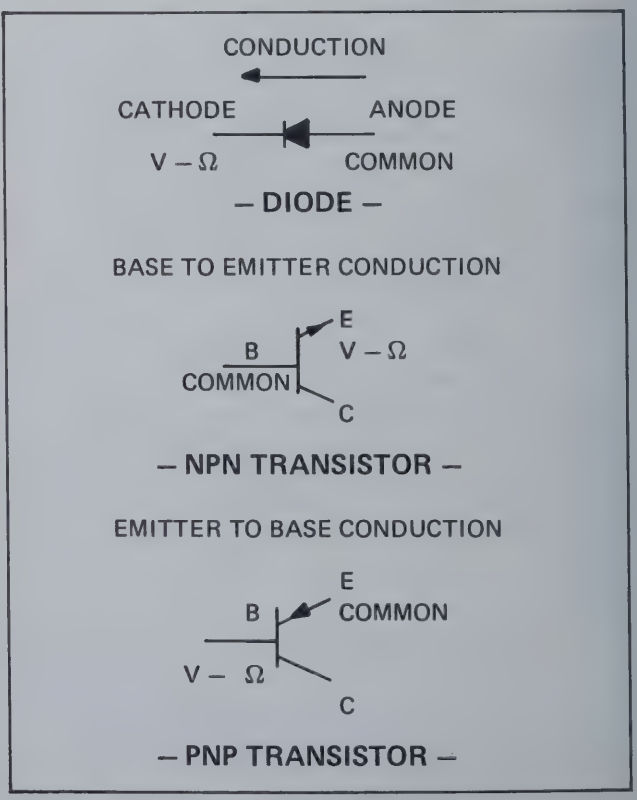


Figure 3–3. Transistor and Diode Testing

3–70. Testing Semiconductor Junctions.

3–71. The 3028B may be used to test transistors, diodes, and integrated circuits to determine the condition of the semiconductor junction. The V–Ω input connector is negative in respect to the COMMON connector and connections should be made as shown in Figure 3–3 to cause forward conduction.

3–72. The voltage applied to semiconductor junctions must be sufficient to cause conduction in the forward direction. The HIΩ mode provides a voltage to 2 volts and a maximum current of 2 mA (2 kΩ range) which is sufficient to cause forward conduction.

Note

Tests on silicon diodes and power transistors should be performed using the HIΩ 2 k range to permit maximum current to flow. Higher resistance ranges generally have too low a measuring current to properly test forward conduction of the junction.

3–73. To test a transistor or diode, first identify the leads as given on the schematic or the manufacturer's data sheet. To determine the condition of a transistor, a measurement of base-emitter and base-collector junctions is required. See Table 3–3 for test conditions for silicon NPN and PNP transistors.

3–74. In-Circuit Measurement of Resistance.

3–75. In-circuit resistances may be measured with the Model 3028B using the LOΩ mode. LOΩ has a maximum voltage of 200 mV full scale which is generally insufficient to obtain conduction in transistor and semiconductor diode junctions.

3–76. In-Circuit Resistance Measurement Precautions.

a. Always turn off all power on the circuit under test and wait sufficient time to discharge all capacitors which may retain a voltage which can damage the ohmmeter (>285 volts rms) or cause measurement errors.

b. Check the schematic of the circuit under test to be certain that the component to be measured is not shunted by others which will cause apparent measurement errors and confusion.

c. When checking sensitive components such as detector diode junctions, minimize ohmmeter measuring current by selecting a higher resistance range (such as 20 k where maximum measuring current is 100 microamperes). Since measuring current is directly proportional to measuring voltage, it is recommended that downscale (<300) measurements be used to minimize ohmmeter power impressed on the device under test.

As an added precaution, short the ohmmeter test leads BEFORE and while initially applying them to the sensitive circuit component under test so that the initial ohmmeter measurement potential is zero. Then release the short and make the resistance measurement. Use of this technique never lets the measuring potential exceed the voltage at which the final resistance measurement is made.

TABLE 3–3. TEST CONDITIONS FOR SILICON TRANSISTORS

Transistor	Connector		DMM		Normal Indication	Faulty Indication
	V – Ω (–)	COMMON (+)	Function	Range		
NPN	Emitter	Base	HIΩ	2 K	≈700Ω	>1000 Ω <400 Ω
NPN	Base	Emitter	HIΩ	20M	>20 MΩ (flashing)	<20 MΩ
NPN	Base	Collector	HIΩ	20M	>20 MΩ (flashing)	<20 MΩ
NPN	Collector	Base	HIΩ	2K	≈700 Ω	>1000 Ω <400 Ω
PNP	Base	Emitter	HIΩ	2K	≈700 Ω	>1000 Ω <200 Ω
PNP	Emitter	Base	HIΩ	20M	>20 MΩ (flashing)	<20 MΩ
PNP	Collector	Base	HIΩ	20M	>20 MΩ (flashing)	<20 MΩ
PNP	Base	Collector	HIΩ	2K	≈700 Ω	>1000 Ω <400 Ω

SECTION 4

THEORY OF OPERATION

4–1. INTRODUCTION.

4–2. This section of the manual contains a description of the circuitry used in the 3028B. Figure 4–1 is a simplified block diagram of the instrument. Basically, the diagram can be broken down into eight functional areas. These are input voltage divider, current shunts, ohms converter, active filter, ac (volts to A) converter circuit, dc analog-to-digital converter, digital display section, and the power supply.

4–3. CIRCUIT DESCRIPTION.

4–4. A complete schematic is shown in Figure 6–1. Refer to this schematic diagram throughout the following circuit description.

4–5. Input Voltage Divider (Reference Designator 100 Series).

4–6. A ten-megohm series connected resistor set is tapped to provide division ratios of 1, 100 and 1000 to 1. Resistor R100 and trimmer potentiometer R101 set the 100 to 1 tap. The value of R102 (90 k) sets the 1000 to 1 tap. Resistor R104 is the basic high-stability calibration resistor in the input attenuator and is the resistive reference for the ohmmeter. The 200 mV and 2 V ranges use the 1 to 1 tap. The 20- and 200-volt ranges use the 100 to 1 tap and the 1200-volt range uses the 1000 to 1 tap.

4–7. Trimmer capacitors are connected across the input voltage divider to maintain a constant attenuation ratio over the frequency band when the input voltage divider is used for ac voltages. High frequency response compensation may be adjusted during calibration with trimmer capacitor C103 for the 1000 to 1 range and with C110 for the 100 to 1 range and C107 when attenuator components are replaced.

4–8. Current Shunts (Reference Designator 200 Series).

4–9. Current shunts consist of three two-terminal and two four-terminal stable noninductive wirewound resistors enclosed in RN200, a resistor package. These series-connected resistors are selected depending on the ac or dc current range selected. Resistances of 1000, 100, 10 1 and 0.1 ohm correspond to the 20 μA, 200 μA, 2 mA, 20 mA, 200 mA, and 2000 mA ranges, respectively. The four-terminal resistor ensures accurate current measurements with variations in lead resistance and components. The input COMMON connections are completed through the resistor network to the analog circuit ground of the DMM.

4–10. The voltage required across any shunt for a display reading of 1000 is 100 mV and the maximum voltage is 200 mV at full scale. The shunts are protected against overvoltage by power diodes CR200 through CR203. Current overload protection above 2 A is provided by quick acting thermal circuit breaker CB10.

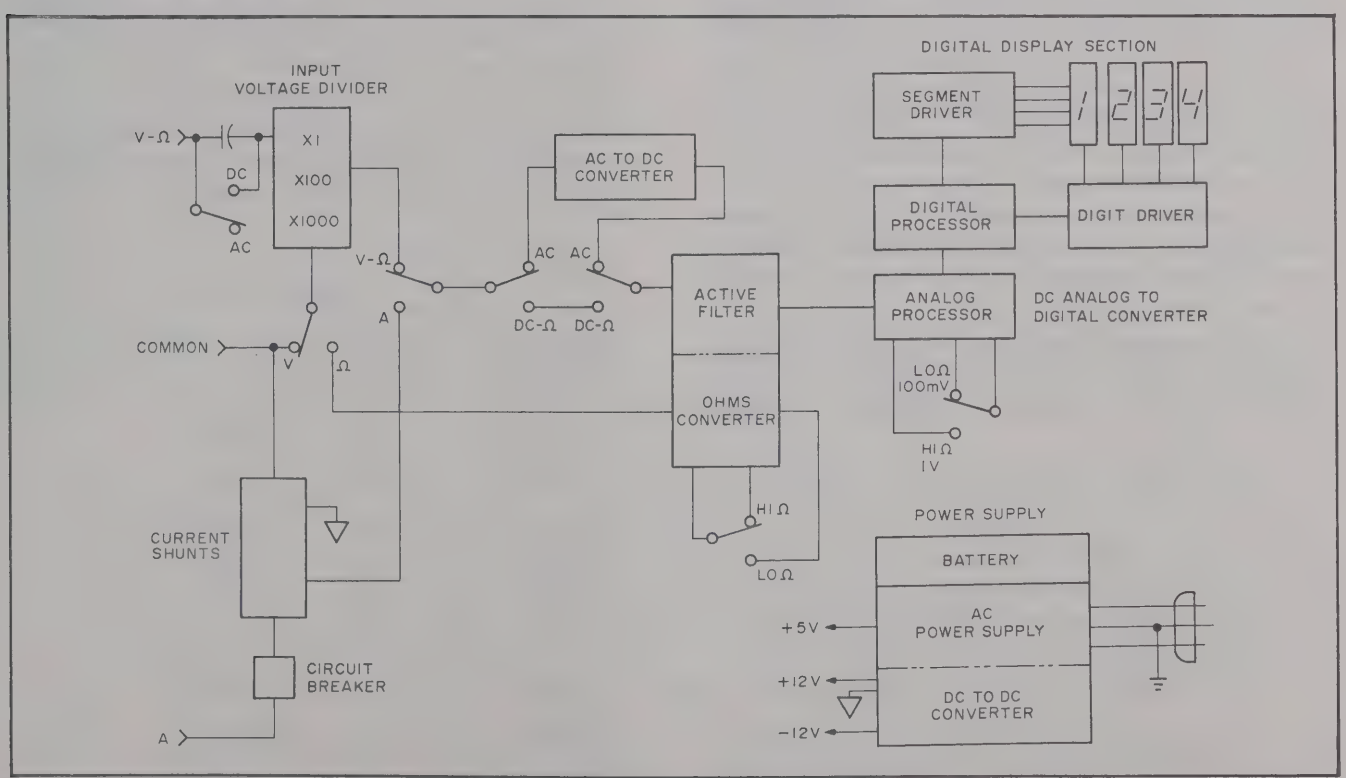


Figure 4–1. Model 3028B, Block Diagram

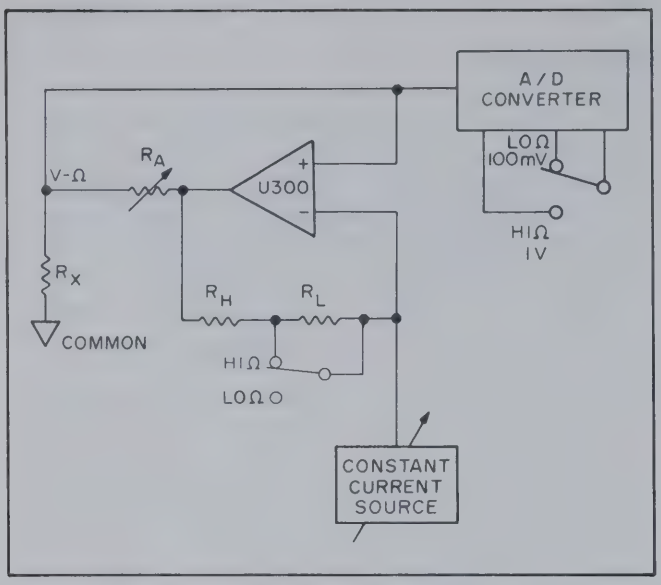


Figure 4–2. Simplified Ohms Converter

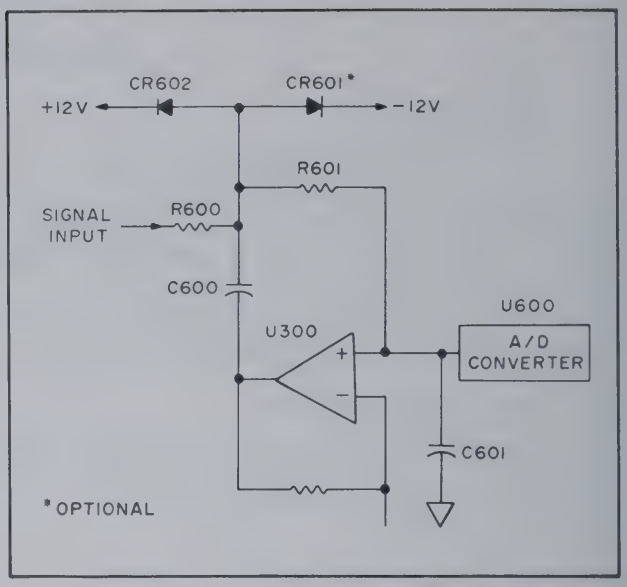


Figure 4–3. Active Filter, Simplified Diagram

4–11. Ohms Converter (Reference Designator 300 Series).

4–12. The ohms converter provides a constant current through the unknown resistance to be measured (R_X). This current creates a voltage drop across R_X which is then measured by the dc analog voltage to digital converter. See Figure 4–2 for a simplified diagram.

4–13. FET input operational amplifier U300 bootstraps the current source comprised of Q300, Q301 and Q302. Q301 is diode-connected to temperature compensate Q300 while Q302 acts as the voltage reference. Constant current level is set by R303 and R304 in the emitter return of Q300. R_A is the input voltage divider, R100, R101, R102, and R104, switched for ohmmeter ranging. With the non-inverting input of U300 connected to the junction of R_A and R_X, current is caused to flow through R_A and R_X. The inverting input of U300 is used to stabilize the voltage and gain across U300 by making the constant current flow through feedback resistors R_H and R_L.

4–14. For a given range and HIΩ or LOΩ mode a constant voltage is maintained across R_A. If R_X is within the range selected, the voltage developed will be directly proportional to R_X.

4–15. The constant voltage across R_A is maintained as indicated in Table 4–1.

4–16. The HIΩ mode requires 2.0 V across R_X at a full scale reading of 1999. In this mode R_H plus R_L are 10 kΩ and provide negative feedback across U300. The sensitivity of the dc analog voltage to digital converter is now set to 2 V. The HIΩ mode is not operative on the 20 and 200 ranges.

4–17. Ohms overload protection is provided by the current limiting of the 7-watt, 10 kΩ input voltage divider resistor R104 and Zener diodes CR300 and CR301 which limit the voltage excursion at the output of U300 to ±12 volts. The dc analog voltage to digital converter is protected against overvoltage by R600, R601, and limiting diodes within U300.

4–18. The ohms overload protection maximum overload current is limited to ±40 mA by the power dissipation ratings of R104 and Zener diodes CR300 and CR301.

4–19. Active Filter.

4–20. The active filter is a two-pole, low-pass filter which rejects ac signals and passes only dc voltages to the dc analog voltage to digital converter. A cutoff frequency (–3 dB) of 8 Hz and a rejection ratio of 38 dB at 60 Hz are provided by this filter. The active filter also prevents overloading of the converter input when large ac voltages are superimposed on the dc voltage to be measured.

TABLE 4–1.

Range	Mode	R_A	Volts across R_A
20, 200	LOΩ	10 kΩ	10
2 kΩ	LOΩ	10 kΩ	1
20 kΩ	LOΩ	100 kΩ	1
200 kΩ	LOΩ	10 MΩ	10
2000 kΩ	LOΩ	10 MΩ	1
2 kΩ	HIΩ	10 kΩ	10
20 kΩ	HIΩ	100 kΩ	10
200 kΩ	HIΩ	100 kΩ	1
2000 kΩ	HIΩ	10 MΩ	10
20 MΩ	HIΩ	10 MΩ	1

4–21. Operational amplifier U300 is used for the active filter as well as the ohms converter. Its noninverting input senses the signal at the input of the converter and feeds it through C600 to the junction of R600 and R601. In effect, it multiplies the resistance of R601 at high frequencies and therefore provides a larger effective time constant for the low-pass filter comprised of R600, R601 and C601. See Figure 4–3 for a simplified diagram of the active filter. Optional diodes CR601 and CR602 provide high peak overload protection for U300 and U600 by limiting at ±12 V.

4–22. AC to DC Converter (Reference Designator 400 and 500 Series)

4–23. The ac to dc converter takes the ac input signal from the input voltage divider or the current shunts and converts it into a dc voltage. This dc voltage is then measured by the dc analog voltage to digital converter. The ac to dc converter is a wideband circuit operating from <15 Hz to beyond 250 kHz and over a dynamic range of <5 mV to beyond 2 V rms. See Figure 4–4 for a simplified diagram of the ac converter.

4–24. The input to the ac converter consists of field effect transistor Q400. This dual gate MOSFET is connected with PNP Q401 to provide high input impedance and low output impedance. It has internal diode protection for input overloads. Resistor R400 is the voltage dropping resistor which limits the FET input current to avoid damage during overloads.

4–25. The input FET follower (Q400) and transistor (Q401) drive the noninverting input of operational amplifier U400. Diode CR401 protects the input of U400 from overloads. Feedback from the output of U400 to its inverting input causes the operational amplifier output to follow the input signal from FET follower Q400. This results in a current flow from ground through R408 plus R409 which is equal to $E_{in}/(R408 + R409)$. Diodes CR402 and CR403 conduct on alternate cycles of the input ac waveform. Therefore, one-half the average current flows through R406. The ac to dc converter is an operational full wave rectifier and the voltage at the junction of CR403 and R406 is sent through low pass filter R411 and C410 for measurement by the dc analog voltage to digital converter. The detector responds to the average of the ac signal input. U500 is a high-performance operational amplifier which in conjunction with CR500 and C501 forms a positive peak detector. The peak value of the input signal is stored in C501 and added to the output from the average responding detector through R504. R411 and R504 are chosen to give optimum rms response at a crest factor of 1.41 ± 20%.

4–26. The input to the ac converter is either 200 mV or 2 V full scale. The circuit is designed to operate over this two decade dynamic range without changing gain. AC conversion gain is adjusted by R409. R506 sets downscale linearity. Crest factor ratio is set by R411 and R504.

4–27. DC Analog Voltage to Digital Converter (Reference Designator 600 Series).

4–28. The dc input voltage is coupled to the analog processor U600 via the precision input voltage divider and a two-pole active low-pass filter. The input voltage to the processor is limited by internal voltage limiters and protective diodes in U300. Ranging resistors in the dc to digital converter are selected by the front panel RANGE switches to provide 20 mV for the 20 mV range, 200 mV for the 200 mV and 20 V ranges, and 2 V for all other ranges. The 20 mV range is switched by FET Q603 and the 200 mV and 2 V ranges are switched by FET Q602.

4–29. The monolithic analog processor contains a bipolar comparator, a bipolar integrating amplifier, two MOSFET input amplifiers, several analog switches and the necessary level shifting drivers to allow the analog and digital processors to be directly interfaced.

4–30. The precision voltage reference Q601 is temperature compensated and supplied by constant current source Q600.

4–31. The feedback resistors which set gain in the analog processor are housed in resistor network RN600 for optimum temperature stability. R604 provides coarse calibration adjustment over the voltage limits reference Q601. R608 is the 200 mV range calibration adjust. R607 serves as the 2 V calibration adjust. R606 is the 20 mV calibration adjust.

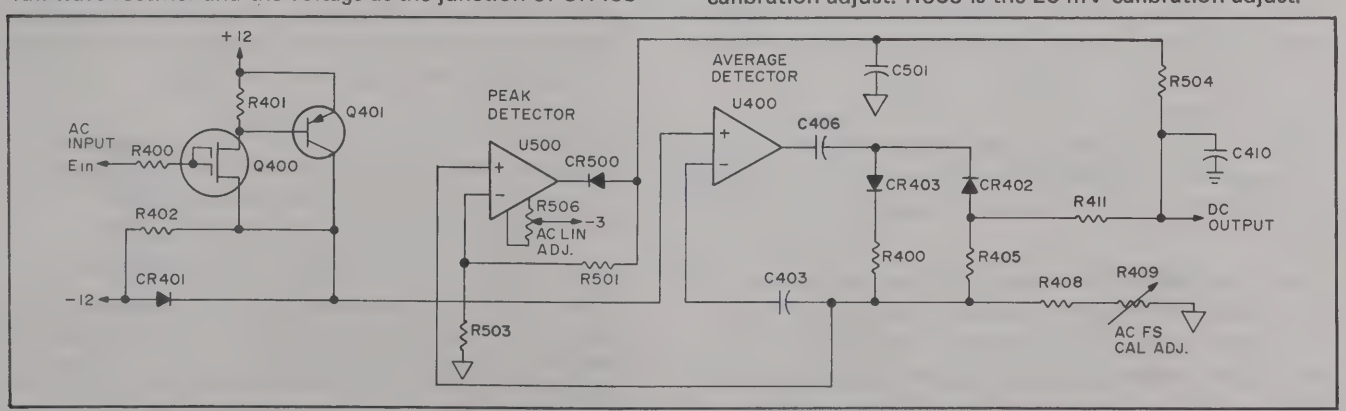


Figure 4–4. AC Converter, Simplified Diagram

4–32. Input offset current compensation is provided by shifting the reference ground level at the input of the analog processor U600. R605 provides offset compensation for a compromise of optimum polarity turnover and display zero adjust. R609 provides 000 adjust for the 20 mV and 20 Ω ranges.

4–33. A measurement cycle consists of two phases: the measure interval and the auto-zero interval. In the measure interval, a conversion technique balances the charge supplied by a current proportional to the input voltage. The accumulation of quantized charges is measured and read as a digital number in BCD format. The units of quantized charge are provided through pulse width modulation of a reference current.

4–34. The auto-zero interval allows the effect of offset, temperatures, and drift to be impressed on the auto-zero storage voltage, which is maintained as a reference by the capacitor C603. Therefore, during the succeeding measure interval, these effects will be balanced out. The input of the buffer amplifier is grounded during this interval.

4–35. Digital Display Circuits (Reference Designator 700 Series).

4–36. The digital processor U700 derives its inputs from analog processor U600 and provides segment control and digit strobing of the multiplexed display. The digital processor combines the counting, storage, and data multiplexing functions with the logic necessary to control the analog processor. Output buffers provide the polarity sign, digit strobe and multiplexed BCD data outputs. The digit scan is an interlaced format of digits 1, 3, 2, and 4.

4–37. The digital processor has a built-in overrange flashing circuit. The presence of a count of 2000 or greater in the BCD counter causes the 3½ digit display to blink off during the zero cycle resulting in a flash rate equal to the sampling rate of four readings per second.

4–38. Decoder driver U702 translates the BCD information from the digital processor to drive the segments of LED numeric readouts DS750, 751 and 752. The common cathodes of these LEDs are strobed by the digital processor U700 and related buffers. DS750 is the least significant digit (LSD).

4–39. The display is tested by illuminating all seven segments in each numeric. Display test is activiated by simultaneously pushing the V and A pushbuttons S3 and S4. U701 then inverts this signal and activates the test mode in U702.

4–40. The numeric "1" is formed by two segments in LED DS753 which also includes the polarity sign. The "1" segments are driven from U701 and Q700. The polarity plus symbol is controlled by U700 and pushbutton switch S2 which illuminates the polarity sign only in the DC modes. U701 strobes DS753 on command from U700.

4–41. Decimal point illumination is automatically controlled by the range pushbutton switches S70, S7, S8, S9, S10 and S12.

4–42. The clock signal for the analog and digital processor is generated by crystal oscillator U703. For optimum normal mode rejection in the analog processor the clock frequency must be a direct multiple of the power line frequency. A clock frequency of 20.48 kHz is chosen since it provides a direct multiple of both 50 and 60 Hz.

4–43. DC-to-DC Power Converter (Reference Designator 800 Series).

4–44. The dc-to-dc power converter transforms the unregulated + 5 volt to provide + 12 and - 12 volt levels. Q800 is the oscillator for step-up autotransformer T800. Q801 and Q802 provide regulation for the dc-to-dc converter. CR801 is the regulator reference zener diode.

*4–45. Pins 7 and 8 (10k) of RN800 couple the clock signal from the dc-to-dc power converter to digital processor U700.

4–46. AC Power Supply (Reference Designator 900 Series).

4–47. The ac power line is connected to T900 which transforms the line voltage to provide a 10-volt dc supply using rectifiers CR900 and CR901, and filter capacitor C900.

4–48. Integrated circuit, three-terminal, 5-volt regulator U900 regulates the output from the rectifiers. *All 5-volt circuits and the dc-to-dc power converter are supplied from U900.

4–49. Rechargeable Battery Supply (Optional).

4–50. The rechargeable battery power supply powers the DMM whenever line voltage is removed or drops below the minimum needed to drive regulator U900. Four nickel cadmium "C" cells are the battery power source.

4–51. The four batteries are wired in series to provide nominally 4.8 volts. Q900 acts as the battery cutout switch to guard against battery reversal and to automatically switch the batteries out of the circuit when ac power is available through U900. The battery output voltage is sufficiently stable during discharge so that the battery supply substitutes for regulator U900 in the +5 volt dc supply.

WARNING

USE ONLY NICKEL CADMIUM "C" CELLS TO POWER THE MODEL 3028B. USE OF ALKALINE OR CARBON ZINC CELLS MAY CAUSE DAMAGE AND VOID THE WARRANTY.

4–52. To charge the batteries, the POWER pushbutton S1 is set to OFF and ac power is applied. The batteries are charged through constant current supply Q901 and Q902 by dc power from rectifier CR900 and CR901. The instrument is not operating when the batteries are being charged. The nominal charging current of 175 mA is maintained throughout the charge cycle.

* Applies only to units with serial prefix 050- and below.

SECTION 5

MAINTENANCE AND CALIBRATION

5–1. INTRODUCTION.

5–2. This section contains information required to maintain the instrument within specifications. The following paragraphs detail:

a. Performance Assurance Checks.

b. Calibration Procedures.

c. Fault Finding (Troubleshooting) details.

d. Preventive Maintenance.

5–3. The instrument is designed with premium components. Like other Ballantine instruments, it will provide many years of satisfactory service. Ballantine recommends that performance assurance checks and preventive maintenance procedures be performed on the following schedule:

a. Routine laboratory service every 12 months or 1,000 hours of use whichever comes first.

b. Service in the field or in extended environments every six months or 450 hours of use whichever comes first.

5–4. Full NBS traceable calibration should be performed once each year. Normally the user will provide recalibration services in his plant. If required, Ballantine will gladly provide this calibration service at our Boonton, N.J. service center for a nominal charge.

5–5. REQUIRED TEST EQUIPMENT.

5–6. Table 5–1 provides a list of test equipment required to properly check, calibrate, and maintain the instrument. Equivalent test equipment meeting all the minimum requirements may be substituted if the recommended items are not available.

TABLE 5–1. REQUIRED TEST EQUIPMENT

Instrument Type	Purpose	Recommended Model	Specifications
DC Voltage Calibrator	DC Voltage Calibration	Fluke 332B	1.0 mV to 1100 V dc. Five-digit resolution. 0.03% accuracy.
AC Voltage Calibrator	AC Voltage Calibration	H-P745A/746A or Fluke 5200/5215	1.0 mV to 1100 V ac. 10 Hz to 110 kHz. Five-digit resolution. 0.05% accuracy.
DC Current Calibrator	DC Current Calibration	Fluke 382A or 760A	10 μA to 1 A dc. Five-digit resolution. 0.05% accuracy.
Resistance Standard	Ohmmeter Calibration	Shallcross 883	10Ω to 10 MΩ. ±0.1% accuracy. Decade dials.
AC/DC True RMS Voltmeter	Line Voltage Measurement	Ballantine 3620A	10 mV to 1 kV, dc and ac true rms. 0.25% accuracy. 4½-digit resolution. 1 μV resolution.
Digital Multimeter	Troubleshooting Tool	Ballantine 3028B	DC volts to 1.2 kV. AC volts to 1.2 kV. 20 Hz to 100 kHz. LOΩ, 100 to 2 MΩ. HIΩ, 1 kΩ to 20 MΩ. AC current to 2A. DC current to 2 A. 3½ digits.
Oscilloscope with probes	Troubleshooting Tool	Ballantine 1032A with 10601C probes	Dual Trace. 5 mV, dc to 15 MHz. 100 ns/cm to 1 sec/cm. 10:1 divider probes.
AC Current Source	AC Current Calibration	Fluke 760A	10 μA to 1 A, ac ±0.2% accuracy.
Line Control Variac	Set Line Voltage	General Radio W5MT3AW	0 V to 135 V (0 V to 270 V).
Frequency Counter	Set A to D Clock frequency	Ballantine 5720A or 5500B	8 digits, 10 Hz to 1 MHz.

5–7. PERFORMANCE ASSURANCE CHECKS.

5–8. The performance assurance checks are "in-cabinet" checks that compare the instrument with the applicable performance specifications. The sample performance test record, Form 5–1, may be used or duplicated to provide permanent performance test records. Beginning with incoming inspection checks, periodic performance assurance checks should be made in the sequence detailed below and before any attempt is made to calibrate the instrument. The performance assurance checks should also be used as part of the troubleshooting procedure and before returning the instrument to regular service after repair, recalibration, or extended storage. *All checks are made at 23°C ±2°C and with COMMON connected to power line earth ground. Use ac power input.*

Note

Prior to making any of the following performance assurance checks set ac line voltage to 120 volts (or 100, 200, or 240 volts). If battery power is used, charge batteries at least 8 hours. Exercise each of the 13 pushbuttons several times to clean switch contacts by self-wiping action.

5–9. Power Supply and Display Check.

5–10. To check the power supply regulation and the display proceed as follows:

a. Connect the instrument to the ac power line through a Variac voltage control unit. Monitor ac voltage with the true rms responding ac voltmeter.

b. Set DMM pushbuttons as follows:

Mode	(S2)	AC
Function	(S4)	A
Range	(S7)	200 μ

c. Set line voltage to 120 ±2 volts (or 100, 220 or 240 volts).

d. Depress POWER pushbutton switch S1 to "ON."

e. Observe that the digital display reads 00.0 to 00.3.

f. Depress V and A pushbuttons S3 and S4 simultaneously.

g. Observe that the display reads 888 as an indication that the display performs satisfactorily.

h. Release V pushbutton S3 but depress A pushbutton S4 to retain current function.

i. Lower line voltage to 102 V (or 87, 196 or 208 volts) and observe that the DMM display does not change. This checks low line voltage operation.

j. Raise line voltage to 130 volts (or 108, 245 or 260 volts) and observe that the DMM display does not change. This checks high line voltage operation. Reset line to 120 volts (100, 220 or 240 volts).

5–11. Battery Check.

Note

This battery check is required only when a rechargeable battery option, such as Option 05, is installed.

a. Continue as in Step 5–10(j) but disconnect ac power cable from the rear panel receptacle of the DMM. Connect earth ground to rear panel ground lug.

b. Observe that the batteries power the unit and that the display does not change.

c. Depress the "V" pushbutton S3. (This releases S4, the A pushbutton.)

d. Depress the 2000 k and 20 M pushbuttons S11 and S12 simultaneously.

e. Observe that the display reads greater than 5.00 to indicate that the batteries are charged. Fully charged batteries will check at above 5.35.

5–12. DC Voltage Accuracy Check.

5–13. To check the dc voltage accuracy of the instrument proceed as follows:

a. Set mode pushbutton switch S2 to "DC."

b. Set function pushbutton switch S3 to "V."

c. Set POWER pushbutton switch S1 to "ON."

d. Depress range pushbutton switch S7 for 200 mV.

e. Connect a short across the V–Ω and COMMON input connectors.

f. Note a display reading of 0.00±2 counts.

g. Depress S70 for 20 mV.

h. Set ZERO screwdriver adjust for 0.00±3 counts.

i. Remove the short from V–Ω and COMMON.

j. Connect the DC voltage calibrator positive output to the V–Ω input connector of the DMM and connect the negative calibrator output to the COMMON connector.

k. Proceed to check dc voltage accuracy at each setting of the voltage calibrator listed in Table 5–2. In each case the digital readout display of the DMM should be within the tolerance shown.

l. For negative readings reverse input leads at the DC voltage calibrator.

5–14. DC Current Accuracy Checks.

5–15. Set the DMM controls as follows:

a. Power (S1) ON

b. Mode (S2) DC

c. Function (S4) A

d. Range (S11) 200 m

5–16. Connect the A input connector of the DMM to the positive output of the dc current calibrator and the COMMON input connector to the negative terminal of the current calibrator.

TABLE 5–2. DC VOLTAGE ACCURACY CHECK

DC Voltage Calibrator Voltage	DMM		Readout Display Limits
	Range	Function	
0.0000	20 m	VDC	–00.3 to +00.3
0.0000	200 m	VDC	–00.1 to +00.1
+0.0100	20 m	VDC	+9.94 to +10.06
+0.0100	200 m	VDC	+09.8 to +10.2
+0.1000	200 m	VDC	+99.8 to +100.2
–0.1000	200 m	VDC	–99.8 to –100.2
+0.1800	200 m	VDC	+179.7 to +180.3
+1.0000	2	VDC	+.998 to +1.002
+10.000	20	VDC	+9.98 to +10.02
+100.00	200	VDC	+99.8 to +100.2
+1000.0	1200	VDC	+998 to 1002

5–17. Check the accuracy at each setting of the dc current calibrator listed in Table 5–3. In each case the displayed readout must be within the tolerances shown.

TABLE 5–3. DC CURRENT ACCURACY

DC Current Calibrator	DMM	
	Range	Readout Limits
00.0 μA	20 μ	–00.4 to +00.4
00.0 μA	200 μ	–00.2 to +00.2
+10 μA	20 μ	+9.90 to +10.10
+100 μA	200 μ	+99.5 to +100.5
+1.000 mA	2 m	+.995 to +1.005
+10.00	20 m	+9.95 to +10.05
+100.0	200 m	+99.5 to +100.5
+1000	2000 m	+995 to +1006

5–18. AC Voltage Accuracy Checks.

5–19. Set the DMM controls as follows:

a. Power (S1) ON
b. Mode (S2) AC
c. Function (S3) V
d. Range (S11) 1200

5–20. Connect the ac voltage calibrator to the V–Ω and COMMON input connectors of the DMM.

5–21. Check the accuracy at each setting of voltage and frequency of the ac voltage calibrator as listed in Table 5–4. In each case the displayed readout must be within the tolerances shown.

5–22. AC Current Accuracy Checks.

5–23. AC current checks are optional. The current shunts within the instrument are used for both ac and dc. They are noninductive and have virtually no effect on frequency response which is determined by the ac to dc converter fully tested in paragraph 5–18 for ac voltage accuracy. Current accuracy is therefore checked for both ac and dc in paragraph 5–14. The following procedure is therefore given for reference only and need not be regularly performed. AC current accuracy checks are not required for the Performance Test Record Form 5–1.

5–24. Set DMM controls as follows:

a. Power (S1) ON
b. Mode (S2) AC
c. Function (S4) A
d. Range (S11) 2000 m

5–25. Connect the ac current calibrator to the A and COMMON input connectors of the DMM.

5–26. Check the accuracy at each setting of current and frequency of the ac current calibrator as listed in Table 5–5.

5–27. Ohms Ranges Accuracy Checks.

5–28. Set DMM Controls as follows:

a. Power (S1) ON
b. Function (S6) LOΩ
c. Range (S7) 200

TABLE 5–4. AC VOLTAGE ACCURACY

(COMMON tied to earth ground lug on rear panel)

AC Voltage Calibrator		DMM	
Voltage	Frequency	Range	Display Limits
0000 mV	500 Hz	20 m	00.0 to 00.5
0000 mV	500 Hz	200 m	00.0 to 00.5
10.00 mV	500 Hz	20 m	9.75 to 10.25
10.00 mV	500 Hz	200 m	09.7 to 10.3
100.0 mV	500 Hz	200 m	98.8 to 101.2
100.0 mV	5 kHz	200 m	98.8 to 101.2
100.0 mV	50 kHz	200 m	97.8 to 102.2
180 mV	500 Hz	200 m	178.1 to 182.0
180 mV	50 kHz	200 m	175.8 to 184.2
180 mV	110 kHz	200 m	170.7 to 189.3
1.000 V	500 Hz	2	.988 to 1.012
1.000 V	5 kHz	2	.988 to 1.012
1.000 V	50 kHz	2	.978 to 1.022
10.00 V	500 Hz	20	9.88 to 10.12
10.00 V	50 kHz	20	9.78 to 10.22
100.0 V	500 Hz	200	98.8 to 101.2
100.0 V	50 kHz	200	97.8 to 102.2
1000.0 V	500 Hz	1200	988 to 1012
1000.0 V	50 kHz	1200	978 to 1022

TABLE 5–5. OPTIONAL AC CURRENT ACCURACY CHECK

(COMMON tied to earth ground lug on rear panel)

AC Current Calibrator		DMM	
Current	Frequency	Range	Display Limits
0000	500 Hz	20 μ	00.0 to 00.7
0000	500 Hz	200 μ	00.0 to 00.5
10.00 μA	500 Hz	20 μ	9.64 to 10.36
100.0 μA	500 Hz	200 μ	98.8 to 101.2
100.0 μA	50 kHz	200 μ	97.3 to 102.7
1.000 mA	500 Hz	2 m	.988 to 1.012
1.000 mA	50 kHz	2 m	.973 to 1.027
10.000 mA	500 Hz	20 m	9.88 to 10.12
10.000 mA	50 kHz	20 m	9.73 to 10.27
100.00 mA	500 Hz	200 m	98.8 to 101.2
100.00 mA	50 kHz	200 m	97.3 to 102.7
1000.0 mA	500 Hz	2000 m	973 to 1027
1000.0 mA	1 kHz	2000 m	973 to 1027

5–29. Connect the Resistance Standard to the V–Ω and COMMON input connectors of the DMM.

5–30. Check the resistance accuracy of the HIΩ and LOΩ ranges of the DMM at each setting of the resistance standard listed in Table 5–6. In each case the displayed readout must be within the tolerances shown.

5–31. CALIBRATION PROCEDURES.

5–32. If any of the Performance Assurance checks show an out-of-tolerance condition, recalibration will be required. Table 5–1 lists the test equipment required to completely calibrate and certify the instrument. If the instrument cannot be adjusted, refer to the troubleshooting and fault finding procedures beginning with paragraph 5–57.

Note

Only a qualified service technician with properly calibrated test equipment should service this instrument, since internal voltages may cause shock hazard. Calibrate at 23°C ±2°C and connect COMMON to earth ground.

5–33. Removal of Covers. The top and bottom covers of the plastic enclosure are fastened together by four screws which are accessible through the bumper feet at the bottom cover. To remove the covers first disconnect ac power cord. Then remove the handle by pulling carefully and firmly on the handle detents until both sides of the handle snaps out of their second detent. Then remove the four screws and carefully pull the top cover up and out from the side sections. Take care not to misplace the four spacer sleeves used to space the top cover on the side supports. These spacers support the unit and provide electrical connections for the metallic coating shield on the top cover and side supports. Always remove NiCad batteries at this point if Option 05 is installed. The side sections may then be removed by pulling up from the bottom cover. The front and rear panels will now be free of support. The printed wiring board may be separated from the bottom cover by removing the retaining screws accessible at the top of the printed wiring board.

Note

When making final calibration always have the bottom cover, panels, and side supports installed with proper electrical interconnection to the metallic coating since it serves as a guard shield to minimize unwanted noise pickup.

5–34. Preliminary Inspection.

5–35. Always check the voltmeter for mechanical damage, loose parts, faulty solder joints, burned resistors, etc. Use a low wattage (25 watts) grounded soldering iron to make repairs and always replace components with exact equivalents to be certain that all performance specifications can be obtained. Use heat shunts when soldering diodes and semiconductors. Do not overhead circuit board printed wiring and pads.

5–36. Internal Adjustments and Test Points.

5–37. See Figure 5–1 for the location of internal adjustments and test points.

5–38. Initial Power Supply Checks.

TABLE 5–6. RESISTANCE ACCURACY CHECKS

Resistance Standard	Function	DMM	
		Range	Display Limits
0000	LOΩ	20	00.0 to 00.5
0000	LOΩ	200	00.0 to 00.5
10.00	LOΩ	20	9.89 to 10.11
100.00	LOΩ	200	99.7 to 100.8
1.0000 k	LOΩ	2 K	.997 to 1.004
1.0000 k	HIΩ	2 K	.997 to 1.004
10.000 k	LOΩ	20 K	9.97 to 10.03
10.000 k	HIΩ	20 K	9.97 to 10.03
100.00 k	LOΩ	200 K	99.7 to 100.3
100.00 k	HIΩ	200 K	99.7 to 100.3
1.000 M	LOΩ	2000 K	994 to 1006
1.000 M	HIΩ	2000 K	997 to 1003
1.000 M	HIΩ	20 M	9.94 to 10.06

5–39. The 3028B has no power supply adjustments but line voltage regulation should be checked before calibration. Vary ac power line voltage with a Variac from 102 to 130 volts (or over the limits given for the operating range selected when using Option 06). Monitor the three dc power supply voltages of the DMM and observe voltages listed in Table 5–7 with a dc voltmeter.

TABLE 5-7. DC POWER SUPPLY LIMITS

Supply	Test Points	Voltage Limits
+5	TP5	+4.70 to +5.30
+12	TP9	+12.7 to +15.0
-12	TP7	-12.7 to -15.0

5–40. Calibration.

5–41. All calibration is performed with ac power turned ON and ac line voltage set to 117 volts (or in the middle of the range selected when using Option 06).

CAUTION

Always perform the calibration in the sequence indicated below.

5–42. Clock Frequency Check.

a. Connect a digital frequency counter to Test Point 8. Ground the counter input to the COMMON input connector of the DMM.

b. Check that the oscillator frequency is 20.48 kHz ± 50 Hz.

c. For units with Serial Prefix below 055. Adjust R801 for a counter reading of 19.65 kHz when using 60 Hz mains or 20.48 kHz when using 50 Hz mains. The setting should be ± 150 Hz.

5–43. Input Offset Adjust R605 and DC Polarity Reversal Test.

a. Set DMM to DC, V, and 200 m.

b. Short input connector V- Ω to COMMON and case ground on rear panel.

c. Adjust R605 (Input Offset Adj.) for a display reading of 00.0. Note that the display does not change ± 1 count more than ten times in ten seconds.

d. Remove input short and connect a dc voltage to V- Ω and COMMON. Set the input voltage for any display reading between +170.0 and +190.0 and note display reading.

e. If batteries (Option 05) are installed, disconnect ac power and observe that reading noted in Step d. does not change more than ± 1 digit. Charge batteries or troubleshoot if reading changes more than ± 1 digit. Restore ac operation for remainder of test.

f. Reverse input leads at the V–Ω and COMMON connectors. Observe that the negative of the display reading noted in Step d. does not change more than ±2 digits for turnover error. If the change is greater, compromise the adjustment of R605 by averaging the setting between steps c. and f.

5–44. ZERO Screwdriver Adjust R609.

a. Set DMM to DC, V, and 20 m.

b. Short input connector V–Ω to COMMON and case ground on rear panel.

c. Adjust R609 (ZERO adjust) screwdriver control for a display reading of –0.02 to +0.02.

5–45. Range Cal Adjust R604.

a. Set R607, the 2 volt adjust and R608, the 200 mV adjust to midrange.

b. Connect the dc voltage calibrator to the V–Ω and COMMON input connectors of the DMM. Apply +190.00 mV.

c. Set DMM Controls to DC, V and 200 m.

d. Adjust R604 Range Cal Adjust for a DMM display reading of +190.0 ±10 digits.

5–46. 200 mV Cal Adjust R608.

a. Maintain the test set up of paragraph 5–45.

b. Adjust R608 (200 mV Cal Adj.) for a DMM display reading of exactly +190.0.

5–47. 2 V Cal Adjust R607.

a. Maintain the test set up of paragraphs 5–45 and 5–46.

b. Set DMM to DC, V, and 2.

c. Set dc voltage calibrator to +1.9000 volts.

d. Adjust R607 (2 V Cal Adj.) for a DMM display reading of exactly +1.900.

5–48. 20 mV Cal Adjust R606.

a. Maintain test setup of paragraph 5–45.

b. Set DMM to DC, V, and 20 m.

c. Set dc calibrator to +19.00 mV.

d. Adjust R606 (20 m V Cal) for a DMM reading of +19.00.

5–49. 1000 to 1 Attenuator DC Adjust R101.

a. Set DMM to DC, V, and 1200.

b. Connect dc voltage standard to the V–Ω and COMMON input connectors. Apply +1000.0 V.

c. Adjust R101(1000 to 1 Att. DC Adj.) for a DMM display reading of +1000.

5–50. Recheck 200 Volt Range DC Calibration.

a. Set DMM to DC, V, and 200.

b. Connect dc voltage standard to the DMM and apply +100.00 V.

c. DMM display should read +100.0.

5–51. LOΩ 2 K Cal Adjust R304.

a. Set DMM to LOΩ and 2 K.

b. Connect resistance standard to V–Ω and COMMON connectors and set standard to 1.900 k Ω.

c. Adjust R304 (LOΩ/2 k Cal Adj.) for a DMM display reading of 1.900. If R304 does not cover the range, select R303 by changing to 7.50 k, 8.25 k or 9.09k Ω or replace Q302.

5–52. HIΩ 2 K Cal Adjust R301.

a. Set DMM to HIΩ and 2 K.

b. Connect 1.9000 kΩ resistance standard to the V–Ω and COMMON connectors.

c. Adjust R301 (HIΩ 2 k Cal Adj.) for a DMM display reading of 1.900.

d. Switch DMM to LOΩ and check that DMM display reads 1.900 ±3 digits or repeat paragraph 5-51.

e. Change resistance standard to 190.00 kΩ and set DMM to HIΩ and 200 k. Check that DMM display reads 190.0 ±3 counts or repeat steps a through c.

5–53. AC 10 mV Linearity Adjust R506.

a. Set DMM to AC, V, and 200 m.

b. Apply 10 mV at 400 Hz.

c. Adjust R506 (AC 10 mV LIN Adj.) for a DMM display of 10.0.

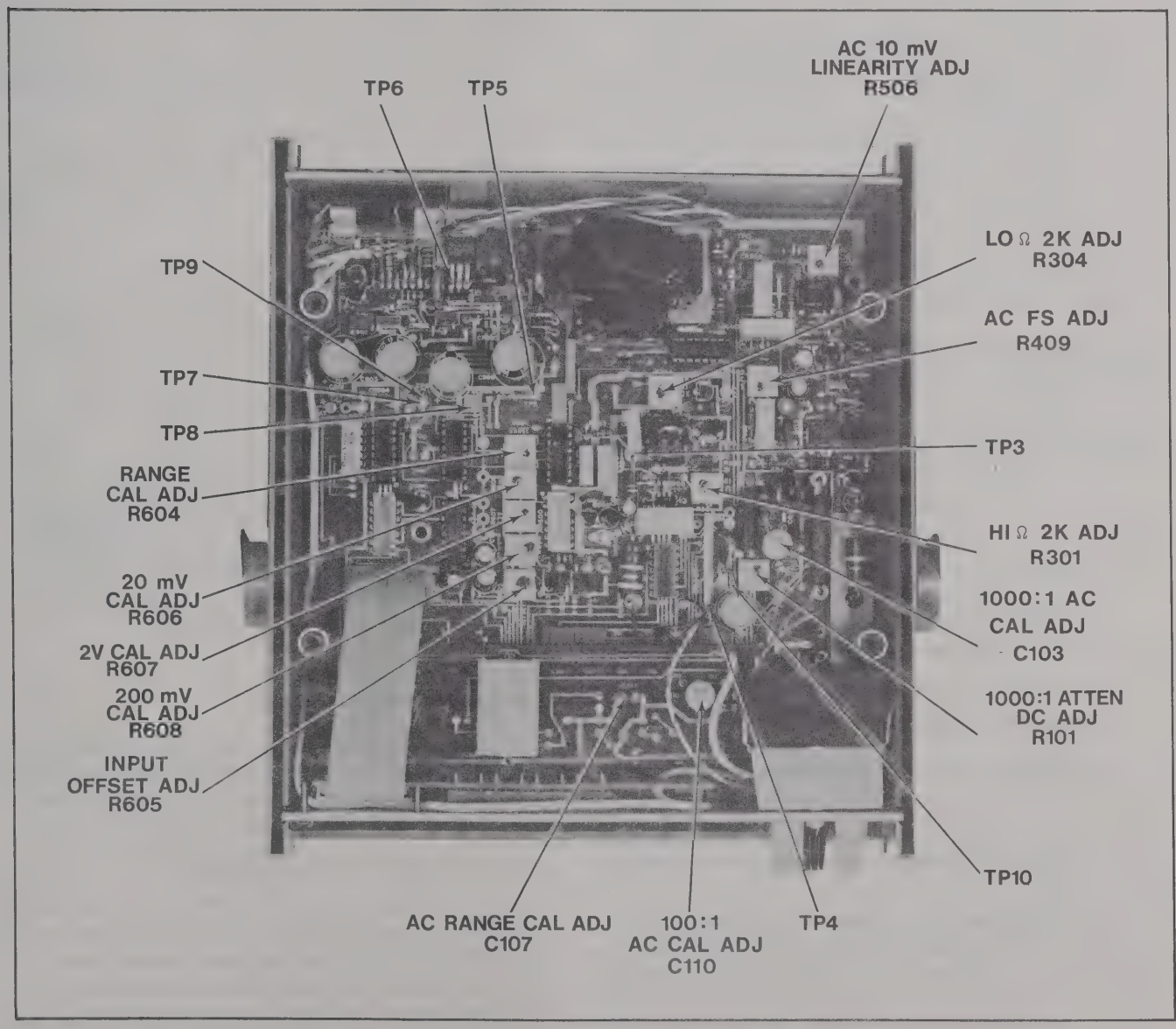


Figure 5–1. Location of Internal Adjustments and Test Points

5–54. AC Full Scale Adjust R409.

a. Set DMM to AC, V, and 200 m.

b. Short V–Ω to COMMON input connector and case ground lug on rear panel.

c. Check that DMM display reads 00.0 to 00.4.

d. Remove input short and connect the ac voltage calibration to the V–Ω and COMMON input connectors. Connect COMMON to case ground lug on rear panel.

e. Apply 190.00 mV at 400 Hz.

f. Adjust R409 (AC FS Adj.) for a DMM display reading of 190.0.

g. Repeat steps 5–52 and 5–53.

5–55. AC 1000 to 1 Cal Adjust C103 and Range Cal Adjust C107.*

a. Set DMM to AC, V, and 1200.

b. Connect the ac voltage calibrator to the V–Ω and COMMON input connectors. Connect COMMON to case ground lug on rear panel.

c. Apply 1000.00 volts at 400 Hz.

d. Observe that the DMM display reads 990 to 1010. If not recheck paragraphs 5–54 (R409), and 5-49 (R101).

e. Increase ac voltage calibrator frequency to 50 kHz.

f. Adjust C103 (AC 1000 to 1 CAL ADJ.) until the display reads 997 to 1002.

g. Set ac voltage calibrator to 5 kHz and note that the display reads 997 to 1003. If display reads above 1003, adjust C107 (AC RANGE CAL ADJ).

If display reads below 997 at 5 kHz, adjust C107 until the 5 kHz and 50 kHz response points are 990 to 1010 and 994 to 1005 respectively.

5–56. AC 100 to 1 Cal Adjust C110.*

a. Set DMM to AC, V, and 20.

b. Connect the ac voltage calibrator to the DMM input.

c. Apply 19.000 volts at 400 Hz.

d. Observe that the DMM display reads 19.00 ±3 digits.

e. Increase ac voltage calibrator frequency to 50 kHz.

f. Adjust C110 (100 to 1 cal adjust) until display reads 99.7 to 100.2.

5–57. TROUBLESHOOTING AND FAULT FINDING.

5–58. The troubleshooting procedures should only be performed when the instrument cannot be calibrated with the calibration procedures listed in paragraphs 5–31 through 5–56. Should the instrument be inoperative or out of specification, follow the fault finding procedures listed below.

5–59. Carefully examine the instrument and check for any visual evidence of trouble. Check for broken wires, burned resistors, loose components, shorts, or open or defective solder joints on the printed circuit board. Check for separation of printed circuit board lands and pads. Check for open, defective, or intermittent switches. Check that connectors are clean and will mate properly. Check that instrument circuit ground is properly connected to the metal coating shield on the plastic case top, bottom and side supports. Check that the power line earth ground is connected only to the front and rear panels. Troubleshoot with COMMON connected to power line earth ground.

5–60. Understand and be familiar with the circuit theory of Section 4. Use the functional block diagram of Figure 4–1 and the schematic diagram to isolate the probable circuit areas which may cause the problem. Always check the power supply voltages. Check for oscillations in the circuitry by using an oscilloscope. Then refer to the fault finding and troubleshooting hints for that circuit. Table 5–8 gives some probable corrections for specific symptoms.

Note

All tests and calibration procedures listed herein consider the normal service conditions of 15°C to +35°C. Should a service condition temperature range of 20°C to 40°C be required then all the calibration settings listed above must be offset to reflect the increased temperature range. Calibrate the instrument with the ambient temperature at 22°C to 25°C and make adjustments by subtracting two least significant digits from the digital display to reflect the higher service condition range of 20°C to 40°C. Always cover top of open instrument to simulate inside case temperature conditions when making adjustments.

5–61. FUSE REPLACEMENT.

5–62. The ac power line fuse F50 is located on the inside of the rear panel. To replace the fuse, remove the covers as described in paragraph 5–33, remove the defective fuse, and snap in the replacement fuse.

5–63. PREVENTIVE MAINTENANCE.

5–64. Cleaning. The instrument should be cleaned as often as operating conditions require. Thoroughly clean both the inside and outside of the instrument. Remove dust from inaccessible areas with low pressure compressed air or vacuum cleaner. Use alcohol applied with a cleaning brush to remove accumulations of dirt or grease from connector contacts and component terminals. Clean the exterior of

*Simulate capacitive effects of top cover when performing this adjustment.

the instrument and the front panel with a mild detergent mixed with water, applying the solution with a soft, lint-free cloth.

5–65. Repair and Replacement. Repair and replacement of electrical and mechanical parts must be accomplished with care and caution. Printed circuit component boards can become warped, cracked, or burnt from excessive heat or mechanical stress. The following repair techniques are suggested to avoid inadvertent destruction or degradation of parts and assemblies.

a. Use a low-heat capacity soldering iron (Weller Model No. W-TCP 35 watt) soldering iron with a 700°F tip 1.5 mm (1/16") to 2.5 mm (3/32") wide.

b. Be sure that the soldering iron tip and the cabinet and COMMON connectors are securely tied to "earth" ground. This avoids possible overvoltage damage to semiconductors and capacitors.

c. To desolder components, use a commercial "solder sipper," (SOLDA PULLT manufactured by Edsyn Products or equivalent) or use solder-removing SODER-WICK, size 3, manufactured by SOLDER REMOVAL CO., Covina, California.

d. To remove a component, clip a heat sink such as long nose pliers, tweezers, or alligator clips onto the component lead and as close to the body of the component as possible. This assures minimum heating of the component while soldering.

Place the soldering iron directly on the component lead on the printed circuit conductor side of the board. Use a de-soldering aid to remove all solder and free the component lead.

TABLE 5–8. TROUBLESHOOTING AIDS

1. Digital display does not illuminate when power switch is "ON".	1. AC power cord not properly inserted or connected. Check power line fuse F50. Check condition of Q800 and Q801, the DC/DC converter drivers, and U900 +5 volt regulator as well as rectifiers, CR900 and CR901, and power switch S1. Check power supply voltages: +12 volts measures between +12.7 to +15.0 V -12 volts measures between -12.7 to -15.0 V +5 volts regulated measures between +4.7 to +5.3 V Replace appropriate components if measurements indicate out of tolerance voltages. Check for other faulty components that cause heating and excessive current drain. Check display drivers U701 and U702. Check Display Test. Replace components if fault is found.
2. Display does not read 0.000 to ±.0001 with 2 V range, V and DC function and V–Ω connector shorted to COMMON.	2. Check clipping diodes CR601 and CR602, if installed, or U300. Short pin 15 of U600 to the common input connector. If display does not show –00.2 to +00.2, check or replace U600 and U700, and display driver circuitry. Check Q601 and measure 6.8 to 9.5 volts across this voltage reference zener. Adjust R605 (Input Offset Adj.) per paragraph 5–43.
3. 10% of Full Range Check. Connect +100 mV DC to the V–Ω and COMMON connectors. Select V and DC function and 2 V range.	3. If readout does not read 0.100, connect input signal to the junction of R600 and S12A. If the display now reads 0.100, check S12A, S5E, S6B, S3B, S2E, and S12B for poor connections. If the display does not read +0.100, transfer the input signal to the junction of CR601 and CR602. Check CR601 and CR602 if the display reads 0.100. If the display does not read 0.100, transfer the input signal to pin 15 of U600. If the display does not read 0.100, check U600, U700 and their related components.

TABLE 5–8. TROUBLESHOOTING AIDS (Continued)

4. Display Test Check. Push V and A pushbuttons.	4. If the display does not read 888, check or replace U702, the decoder driver. Check the +5 volt regulated supply to see that it measures +4.7 to +5.3 volts. If one digit is not functioning, check U701. If some segments of the display are not lit, sequentially tie pins 9 thru 15 of U702 to the +5 volt supply and observe that one row of segments of the display are lit at any one time. This checks faulty U702 decoder driver. Also check RN700 and the LED readout DS750 thru DS752 and its cable assembly.
5. Full Range Check. Connect +1.900 volts DC to the V–Ω and COMMON connectors. Select V and DC function and 2 V range.	5. Observe +1.900 ±2 digits. If display is not in tolerance, recalibrate R608 and R607 the 200 m volt and 2 volt range calibrators. Also check switches S5A, S7E, S6F, S4D and S9B. Check reference diode Q601. Use a frequency counter to check clock frequency, 20.48 kHz for 50 Hz and 60 Hz power line operation. If either "1" digit of display or "+" symbol does not light up, check DS753, Q700, Q701, U701, S2B, S3D, and S4E.
6. Check negative sign. Repeat step 5 but apply –1.8 V DC.	6. Negative sign must illuminate on DS753. If not, check U700, U701, and Q700. If display reads more than 3 digits difference between plus input polarity (step 5) and minus input polarity (step 6), check for leaky diodes CR601 and CR602. Check U3 for excessive input current and clean P.C. board since leakage may exist at the input leads between V–Ω connector and pin 15 of U600. Check adjustment of R605 (Input Offset Adj.) since it also controls polarity turnover error. See paragraph 5–43.
7. Decimal Point Test. Select DC A function and 200 mA range.	7. Observe that no decimal point is lit and the display reads –022 to +002. Select 200 mA range and observe that the display reads –00.2 to +00.2. Select 20 mA range and observe that the display reads –0.02 to +0.02. Select 2 mA range and observe that the display reads –.002 to +.002. Select 200 μA range and observe that the display reads –00.2 to +00.2. Select 20 mA range and after setting ZERO adjust, observe that display reads –0.03 and +0.03. If any of these decimal points do not light, check the respective LED (DS750 thru DS752). Check R705, S7C, S70, S9E, S10E, and S12D.

TABLE 5–8. TROUBLESHOOTING AIDS (Continued)

8. Accuracy Tests. See details in Performance Assurance Checks (paragraph 5–7).	8. DC volt calibration not OK, check input voltage divider R101, R102, R104, R600, R601, Q602 Q603, and their associated switches. KΩ tests not OK then check U300, constant correct source Q300, Q301 and Q302, and their associated components. If 100 Ω RANGE faulty, also check R303 and R304 as well as S5B and S6E. Also check S3E, S4B, S7B, S10D, and S5C. DC A tests not OK, check current shunt resistor DIP RN200 as well as condition of CR200 through CR203. Check associated switches. AC voltage tests not OK, check AC converter U400, Q400, Q401, U500, and associated switches and components. AC A tests not OK, recheck DC A tests and AC voltage tests. Then check S4A, S2D, S2A, and S3A.
9. Intermittent Switches.	9. When the multimeter has been stored for a period of time or has been exposed to caustic fumes, acid fumes, oil fumes, hydrogen sulfide, or other contaminants, the pushbutton switches may become noisy or intermittent even though specially treated high-quality silver-plated contacts are used throughout. Push each button ten or more times to permit self-wiping action of switches to clean the contacts and eliminate the problem. If at the end of life or after extensive exposure the switches continue to be noisy, they should be replaced with new components. Periodically lubricate switches with silicone spray contact lubricant. See paragraph 5–66.
10. Battery Operation Not Functional.	10. Check that batteries are charged and or charge batteries for 8 to 16 hours. Replace batteries when they do not power DMM for at least 3 hours. Open top cover and check that batteries are installed and seated properly. * Observe that ballast lamp DS900 is installed and lights brightly to indicate batteries are charging when POWER switch (S1) is OFF and ac line power is applied.

* Applies only to units with serial prefix 050- and below.

Straighten the bent over component lead with long nose pliers.

Pull the component out of the hole.

If a component is obviously faulty or damaged, simply clip the leads close to the body of the component and remove the remaining leads thru the conductor side of the circuit board.

CAUTION

Always use a short soldering cycle since excessive or prolonged heat may destroy the laminate bond and lift the copper conductors from the circuit board or cause immediate degradation or latent damage to the components.

e. Always clean the component lead holes by heating the solder on the circuit board conductor pad, then quickly remove the soldering iron and insert a pointed non-metallic object such as a toothpick to clean the hole. Never let solder cover the hole, since the incoming new component lead may then push the pad from the circuit board.

f. To install a new component, straighten and shape the leads. Insert the component into the proper holes. Bend the leads at the conductor side of the circuit board so they fall over the pad and extend over the foil of the incoming conductor path. Cut the bent lead approximately 2.5 mm (3/32") from the hole.

Clip a heat sink to the component lead at the body of the component. Heat the lead and pad with a soldering iron and use fresh solder (60-40) as required to cover the lead and form a meniscus over the hole to assure a good electrical connection.

g. Clean excess flux from the connection and surrounding area. Use TF Freon spray cleaner (such as Miller Stevenson Chemical Co., Type MS-180, Ballantine P/N 80-10004-0A) and use light air pressure (5 to 20 PSIG) and a clean soft brush to clean board and components. Use a humidity seal spray (such as Humiseal, Columbia Technical Corp., 1015, Ballantine P/N 80-10005-0A) to seal board and protect against humidity.

Note

Do not touch cleaned board or excessively handle components to avoid unwanted leakage which may affect performance when exposed to high humidity.

h. Always replace a component with its exact duplicate as specified in the parts list.

5–66. REPLACING PUSHBUTTON SWITCHES.

a. Pushbutton switches may be disassembled for replacement of worn switch wipers and return springs. This saves unsoldering the multicontact switch. New parts must be taken from replacement switch assemblies which may be ordered as spare parts. To obtain access to pushbutton switches remove front panel and pushbuttons. Hold the return spring. Use a long nose plier to pull up and away on the "U" shaped retainer. Remove the spring. On S1 and S2 free the detent spring and pin. Carefully slide the switch bar out the rear of the switch. Access is then obtained to the individual switch contact sliding springs. Clean the switch and lubricate contacts.* Place the new contact springs into the switch bar and carefully reassemble the switch bar thru the rear of the switch assembly. To simplify assembly reinsert two switch contact slider springs at a time. When all contact slider springs are in place and the push bar is fully extended out the front of the housing, replace the detent, the return spring and the "U" retainer. Operate the rebuilt switch several times to be sure all parts are in place. Then reassemble and test the instrument.

b. It is recommended that all contact slider springs be replaced in all 12 switches. If the entire switch assemblies are to be replaced, unsolder the small upper printed wiring board. Then use a solder pot or solder wave (rather than soldering iron and solder sucker) to remove the switch assemblies.

c. Do not clean switch with Freon or other solvents. Periodically lubricate all switch contacts with a light application of spray lubricant.*

*Use switch contact lubricant and cleaner such as Electrolube Contact Treatment Oil 2AX or Centralab Switch Contact Spray Lubricant, Ballantine P/N 80100090A.

PERFORMANCE TEST RECORD

BALLANTINE MODEL 3028B, OPTION _____ SERIAL NUMBER _____

1.	120-Volt Check	(0.00 ±3 LSD)	_____ (✓)
2.	Display Test	(888)	_____ (✓)
3.	102-Volt Lo Line Check	(0.00 ±3 LSD)	_____ (✓)
4.	130-Volt HI Line Check	(0.00 ±3 LSD)	_____ (✓)
5.	Battery Test (Option 05 installed)	(>5 volts display reading)	_____ (✓)

6. DC Voltage Calibration Check

Calibrator Voltage	DMM			
	Range	Function	Readout Display Limits	Reading
0.0000	20 m	VDC	–00.2 to +00.2 (zero)	
0.0000	200 m	VDC	–00.1 to +00.1	
+0.0100	20 m	VDC	+9.95 to 10.05	
+0.0100	200 m	VDC	+09.8 to +10.2	
+0.1000	200 m	VDC	+99.8 to +100.2	
–0.1000	200 m	VDC	–99.8 to –100.2	
+0.1800	200 m	VDC	+179.7 to +180.3	
+1.0000	2	VDC	+.998 to +1.002	
+10.000	20	VDC	+9.98 to +10.02	
+100.00	200	VDC	+99.8 to +100.2	
+1000.0	1200	VDC	+998 to 1002	

7. DC Current Calibration Check

DC Current Calibrator	DMM		
	Range	Readout Limits*	Reading
00.0 μA	20 μ	–0.03 to +0.03 (zero)	
00.0 μA	200 μ	–00.2 to +00.2	
+10 μA	20 μ	+9.92 to +10.08	
+100 μA	200 μ	+99.5 to +100.5	
+1.000 mA	2 m	+.995 to +1.005	
+10.00	20 m	+9.95 to +10.05	
+100.0	200 m	+99.5 to +100.5	
+1000	2000 m	+995 to +1005	

*Readout limits do not apply to Options 24, 39, and 39A.

Form 5–1. Performance Test Record

8. AC Voltage Calibration Check

(COMMON tied to earth ground lug on rear panel)

AC Voltage Calibrator			DMM	
Voltage	Frequency	Range	Display Limits	Reading
0000 mV	500 Hz	20 m	00.0 to 00.5 (zero)	
0000 mV	500 Hz	200 m	00.0 to 00.5	
10.00 mV	500 Hz	20 m	9.75 to 10.25	
20.00 mV	500 Hz	200 m	19.4 to 20.6	
100.00 mV	500 Hz	200 m	98.8 to 101.2	
100.0 mV	5 kHz	200 m	98.8 to 101.2	
100.0 mV	50 kHz	200 m	97.8 to 102.2	
180 mV	500 Hz	200 m	178.0 to 182.0	
180 mV	50 kHz	200 m	175.8 to 184.2	
1.000 V	500 Hz	2	.988 to 1.012	
1.000 V	5 kHz	2	.988 to 1.012	
1.000 V	50 kHz	2	.978 to 1.022	
1.000 V	110 kHz	2	.947 to 1.053	
10.00 V	500 Hz	20	9.88 to 10.12	
10.00 V	50 kHz	20	9.78 to 10.22	
100.0 V	500 Hz	200	98.8 to 101.2	
100.0 V	50 kHz	200	97.8 to 102.2	
1000.0 V	500 Hz	1200	988 to 1012	
1000.0 V	50 kHz	1200	978 to 1022	

9. Ohms Calibration Check

Resistance Standard	DMM			
	Function	Range	Display Limits	Reading
0000	LOΩ	20	00.0 to 00.5 (zero)	
0000	LOΩ	200	00.0 to 00.5	
10.00	LOΩ	20	9.89 to 10.11	
100.00	LOΩ	200	99.7 to 100.6	
1.0000 k	LOΩ	2 K	.997 to 1.006	
1.0000 k	HIΩ	2 K	.997 to 1.006	
10.000 k	LOΩ	20 K	9.97 to 10.06	
10.000 k	HIΩ	20 K	9.97 to 10.06	
100.0 k	LOΩ	200 K	99.7 to 100.6	
100.00 k	HIΩ	200 K	99.7 to 100.6	
1.0000 M	LOΩ	2000 K	994 to 1006	
1.000 M	HIΩ	2000 K	997 to 1003	
1.000 M	HIΩ	20 M	9.94 to 10.06	

_____ _____

Signature *Date*

Ballantine Laboratories, Inc.
P.O. Box 97, Boonton, New Jersey 07005, U.S.A.
Telephone: 201-335-0900 TWX: 710-987-8380

SECTION 6

REPLACEABLE PARTS LIST AND CIRCUIT SCHEMATIC DIAGRAMS

The replacement parts listed are available from the vendors listed or from Ballantine Laboratories. Your local Ballantine Field Engineering Representative may also carry a stock of parts and can assist you. If pricing quotations are required for parts and or repairs your local representative will give the most rapid service or you may contact the Ballantine Factory directly.

When ordering replacement parts always give the following information:

a) Instrument Model number
b) Serial number
c) Ballantine Part number
d) Schematic Symbol number
e) Identification and description of the part

Ballantine will do its best to improve the instrument and make changes in style of components and replacement parts. Replacement parts may differ in appearance from those found in your instrument but are always equal or superior in performance. Where necessary minor mechanical modifications may be required in the replacement of the components.

Parts are generally available locally for most replacements. The parts list calls out the recommended vendors where applicable.

The instrument may substitute alternate components but the use of parts specified in this parts list is recommended. A part similar to the part initially installed at the factory may be used, i.e., a 5% composition resistor may be replaced with a similar part or a 5% film resistor or the preferred 1% metal film resistor. Use of the preferred component will always simplify calibration and speed repairs.

Any selected component is generally identified in this manual and may be replaced with a similarly valued part unless reselection is required due to replacement or change of its related part. The schematics and calibration procedures identify selected components and replacement procedures.

The Manufacturer Code is taken from Federal Supply Code Cataloging Handbooks H4-1, H4-2, and H4-3. Ballantine Code is 50423.

The following parts coding are used:

CVC	Capacitor, Variable, Ceramic
CCT	Capacitor, Ceramic, Tubular
CFP	Capacitor, Fixed, Plastic
CCD	Capacitor, Ceramic, Disc
CYF	Capacitor, Mylar, Foil
CMD	Capacitor, Mica, Dipped
CMM	Capacitor, Mica, Molded
CEA	Capacitor, Electrolytic, Aluminum
CET	Capacitor, Electrolytic, Tantalum
DGP	Diode, General Purpose
DZG	Diode, Zener, General Purpose
DRP	Diode, Bridge, Power
FLT	Filter
ICP	Integrated Circuit
TRQ	Transistor
RFF	Resistor, Fixed, Film
RFC	Resistor, Fixed, Composition
RVC	Resistor, Variable, Composition
RFW	Resistor, Fixed, Wirewound
SWC	Switch
LMP	Lamp
TRX	Transformer

Resistors may generally be replaced by Corning Electronics (CCW) type N-55, N-60 and C-32. Allen Bradley carbon composition resistors type EB may also be used but should generally be avoided (except for emergency replacements) in favor of the preferred part listed in this parts list.

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
C100	07-10336-0A	CBM 47.0NF 1.6KV +-10%	80031	MEPCO C281/1600/A47K
C102	07-10350-0A	CMD 470.0PF 500.0 V TCE 2%	84171	ARCO DM15ED470G03 ARCO
C103	07-10360-0A	CVO 10-60 350.0 V N750	50423	STET-TRUSH IDSTRIK022
C104	07-20135-0A	CMD 22.0PF 5%	84171	DM15-220J OR EQUIV.
C105	07-10354-0A	CMD 1.0NF 500.0 V +- 1%	84171	ARCO DM-19-E-D-1000-F-N-U
C.107	07-02458-0A	CVP .25- 1.5 PF 2KV	74970	JOHNSON TYPE 273-1-1
C110	07-10360-0A	CVO 10-60 350.0 V N750	50423	STET-TRUSH IDSTRIK022
C300	07-10137-0A	CMO 160. PF 500. VJ	72136	ELMENCO DM15FD161J03
C301	07-10137-0A	CMO 160. PF 500. VJ	72136	ELMENCO DM15FD161J03
C.302	07-20094-0A	CCD .1UF 25.0 V +-20%	91418	M25-1
C.401	07-10120-0A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C.403	07-10341-0A	CBM 470.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A470K
C.404	07-10120-0A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C.406	07-10258-0A	CET 68.0UF 15.0 VK DIP TAN	56289	SPRAG 196D686X9015-LA3
C407	07-10492-0A	CEA 47.0UF 16.0 V	0	CAPAR CRE SERIES 47UF 16V
C408	07-10492-0A	CEA 47.0UF 16.0 V	0	CAPAR CRE SERIES 47UF 16V
C.409	07-10087-0A	CMD 390.0PF 100 VIJ	84171	ARCO TYPE RDM15-391J
C410	07-10341-0A	CBM 470.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A470K
C.501	07-10341-0A	CBM 470.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A470K
C.502	07-10120-0A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C.503	07-10120-0A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C.504	07-09551-0A	CCD 10.0PF 1.0 KVJ NPO	56289	ARC TYP CCD-100
C600	07-10337-0A	CBM 68.0NF 630.0 V +-10%	80031	REFER TO 07-10250-0A
C601	07-10338-0A	CBM 33.0NF 400.0 V +-10%	80031	MEPCO C280MCF/A33K
C602	07-10120-0A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C603	07-10339-0A	CBM 100.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A100K
C604	07-10120-0A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C.605	07-10120-0A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C606	07-10441-0A	CBM 10.0NF 400.0 V	80031	MEPCO C280MCF/A10K
C.701	07-10492-0A	CEA 47.0UF 16.0 V	0	CAPAR CRE SERIES 47UF 16V
C.702	07-10492-0A	CEA 47.0UF 16.0 V	0	CAPAR CRE SERIES 47UF 16V
C.703	07-10492-0A	CEA 47.0UF 16.0 V	0	CAPAR CRE SERIES 47UF 16V
C801	07-10440-0A	CEA1000.0UF 16.0 V	0	CAPAR CRE 1000UF/16V
C802	07-10440-0A	CEA1000.0UF 16.0 V	0	CAPAR CRE 1000UF/16V
C803	07-10440-0A	CEA1000.0UF 16.0 V	0	CAPAR CRE 1000UF/16V
C.804	07-20094-0A	CCD .1UF 25.0 V +-20%	91418	M25-1
C.805	07-10222-0A	CYF 15. NF 250. VK	73445	AMPREX C280AE/A15K
C.806	07-20094-0A	CCD .1UF 25.0 V +-20%	91418	M25-1
C.807	07-20094-0A	CCD .1UF 25.0 V +-20%	91418	M25-1
C.900	07-10440-0A	CEA1000.0UF 16.0 V	0	CAPAR CRE 1000UF/16V
CB10	19-10035-1E	CBK 2A BREAKER FAST LNG SHFT	50423	BLI REV.
CR200	05-10063-0A	DRP 1N5400 50 3A	4713	MOT SI
CR201	05-10063-0A	DRP 1N5400 50 3A	4713	MOT SI
CR202	05-10063-0A	DRP 1N5400 50 3A	4713	MOT SI
CR203	05-10063-0A	DRP 1N5400 50 3A	4713	MOT SI
CR300	05-09477-0A	DZG 1N5231A 5.1 .5W 20M 10%	4713	MOT SI D07
CR301	05-10099-0A	DZG 1N5243A 13.0VJ .5W	4713	MOT 1N5243A 13V ZENER
CR401	05-07920-0A	DGP 1N4148 75 10M	7263	FCH SI D035
CR402	05-07920-0A	DGP 1N4148 75 10M	7263	FCH SI D035
CR403	05-07920-0A	DGP 1N4148 75 10M	7263	FCH SI D035
CR500	05-07920-0A	DGP 1N4148 75 10M	7263	FCH SI D035
CR602	05-10103-0A	DXS PAD50 35.0V .50M	17856	SIL PAD50 PICOAMP 51
CR801	05-08058-0A	DGP 1N4006 400 1A	15238	ITT SI D046
CR802	05-07920-0A	DGP 1N4148 75 10M	7263	FCH SI D035
CR803	05-07920-0A	DGP 1N4148 75 10M	7263	FCH SI D035
CR804	05-07920-0A	DGP 1N4148 75 10M	7263	FCH SI D035
CR805	05-10099-0A	DZG 1N5243A 13.0VJ .5W	4713	MOT 1N5243A 13V ZENER
CR806	05-07920-0A	DGP 1N4148 75 10M	7263	FCH SI D035
CR900	05-08058-0A	DGP 1N4006 400 1A	15238	ITT SI D046
CR901	05-08058-0A	DGP 1N4006 400 1A	15238	ITT SI D046
CR902	05-08058-0A	DGP 1N4006 400 1A	15238	ITT SI D046
CR903	05-07920-0A	DGP 1N4148 75 10M	7263	FCH SI D035
CR904	05-10137-0A	DGP ERA81-004 40V @ 1 AMP	0	FUS7 SEMICONDORS ERA81-004

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
DS750	21-10040-0A	IND 0.43 IN HI EFF RED C.C.	28480	HP 5082-7653 COMMON CAT.
DS751	21-10040-0A	IND 0.43 IN HI EFF RED C.C.	28480	HP 5082-7653 COMMON CAT.
DS752	21-10040-0A	IND 0.43 IN HI EFF RED C.C.	28480	HP 5082-7653 COMMON CAT.
DS753	21-10041-0A	IND 0.43 IN.HIEF.RED CC +-1	28480	HP 5082-7656 COMMON CAT.
F50	19-10036-0A	FUS .125A NORMAL-BLO	75915	LITTELFUSE TYP3AG NORMBLO
J1	31-30126-0A	CON FLEXPRINT 20 PINS PC MT	26394	ANSLEY 609 2003
J10	31-10132-0A	BPS 10MM GREY	50423	BLI ELMA INTERLK 024-2010
J20	31-10132-0A	BPS 10MM GREY	50423	BLI ELMA INTERLK 024-2010
J30	31-10133-0A	BPS 10MM BLACK	50423	BLI ELMA INTERLK 024-2020
J50	31-10000-0A	REC AC POWER	82389	SWITCHCRAFT
L..10	46-10002-0A	FRB FER BD 4AMAT.0471D	2114	FERROX CUBE 56590 65/HA
L..20	46-10002-0A	FRB FER BD 4AMAT.0471D	2114	FERROX CUBE 56590 65/HA
L..30	46-10002-0A	FRB FER BD 4AMAT.0471D	2114	FERROX CUBE 56590 65/HA
Q300	10-09473-0A	TRQ 2N3906 PNP 1 40 PTO-92	4713	MOT 1 200M 60
Q301	10-09473-0A	TRQ 2N3906 PNP 1 40 PTO-92	4713	MOT 1 200M 60
Q302	05-10076-1B	DZG 2N4274 6.8V 1.5M+-10%	50423	BLI SELECT.FROM 051007638
Q400	10-10105-1A	TRQ 40673 SEL FOR LEAK	50423	BLI SEL/99100385A
Q401	10-09473-0A	TRQ 2N3906 PNP 1 40 PTO-92	4713	MOT 1 200M 60
Q600	10-10099-0A	TRQ E507	17856	SILICONIX
Q601	05-10076-1B	DZG 2N4274 6.8V 1.5M+-10%	50423	BLI SELECT.FROM 051007638
Q602	10-10128-0A	TRQ E111 N J FET TO-106	17856	SILICONIX E111 RDS=300HM
Q.603	10-10130-0A	TRQ E108 N J FET TO-106	17856	SILICONIX E108 A0S=80HMS
Q700	10-09473-0A	TRQ 2N3906 PNP 1 40 PTO-92	4713	MOT 1 200M 60
Q.801	10-10087-0A	TRQ 2N5193 PNP 1 40 P77-03	4713	MOT 40 2M 10
Q803	10-10043-0A	TRQ 2N3904 NPN 1 40 PTO-92	4713	MOT 1 300M 40
Q901	10-09473-0A	TRQ 2N3906 PNP 1 40 PTO-92	4713	MOT 1 200M 60
Q.902	10-10087-0A	TRQ 2N5193 PNP 1 40 P77-03	4713	MOT 40 2M 10
Q.903	10-10087-0A	TRQ 2N5193 PNP 1 40 P77-03	4713	MOT 40 2M 10
R100	12-12867-0A	RFF 9.76M 2.0 W 1%	3888	PYROFILM PME 64T9 2.5KV
R101	09-10009-0A	RVC 250.0 K 0.5 W K+-10%	73138	HEL TYP 72PM
R102	12-12937-0A	RFW 90.0 K 1.0 W .05%NI	50423	RCD S102 NON-IND .75 LEAD
R104	12-12861-0A	RFW 10.0 K 7.0 W 0.05%	50423	RCD CORP NON-IND
R105	12-01095-0A	RFC 18.0 M 500.0MW J+- 5%	1121	A-B TYP EB
R201	89-10938-1A	ASY 9632M 2 AMP SHUNT	50423	
R300	12-12389-0A	RFF 8.45K 500.0MW F+- 1%	16299	CGW RN55D 8451 F
R301	09-10005-0A	RVF 1.0 K 0.5 W K CERMET	73138	HELIPOT 72PM
R302	12-12300-0A	RFF 1.0 K 250 MW F+-1%	16299	CGW RN55D 1001 F
R303	12-12376-0A	RFF 6.19K 250.0MW F+- 1%	16299	CGW RN55D 6191 F
R304	09-10005-0A	RVF 1.0 K 0.5 W K CERMET	73138	HELIPOT 72PM
R305	12-01048-0A	RFC 4.7 K 500.0MW J+- 5%	1121	A-B TYP EB
R306	12-12500-0A	RFF 100.0 K 250.0MW F+- 1%	16299	CGW RN55D 1003 F
R400	12-12863-0A	RFC 150.0 K 2.0 W 5%	1121	A-B HB
R401	12-01057-0A	RFC 1.0 K 500.0MWJ +- 5%	1121	A-B TYP EB
R.402	12-08011-0A	RFC 10.0 K 250.0MW J+- 5%	1121	A-B TYP CB
R.404	12-01007-0A	RFC 2.0 M 500.0MW J+- 5%	1121	A-B TYP EB
R.405	12-12328-0A	RFF 1.96K 250.0MW F+- 1%	16299	CGW RN55D 1961 F
R.406	12-12328-0A	RFF 1.96K 250.0MW F+- 1%	16299	CGW RN55D 1961 F
R.408	12-12292-0A	RFF 909.0 250 MW F+-1%	16299	CGW RN55D 9090 F
R.409	09-10004-0A	RVF 100.0 0.5 W M	73138	HEL TYP 72PM
R.410	12-12340-0A	RFF 2.61K 250.0MW F+- 1%	16299	CGW RN55D 2611 F
R.411	12-08958-0A	RCF 240.0 K 500.0MW J+- 5%	1121	A-B TYP EB
R.412	12-08958-0A	RCF 240.0 K 500.0MW J+- 5%	1121	A-B TYP EB
R.501	12-12400-0A	RFF 10.0 K 250.0MW F+- 1%	16299	CGW RN55D 1002 F
R.502	12-01072-0A	RFC 39.0 500.0MW J+- 5%	1121	A-B TYP EB
R.504	12-08029-0A	RFC 1.0 M 250.0MW J+- 5%	1121	A-B TYP CB
R505	12-08030-0A	RFC 4.3 K 250.0MW J+- 5%	1121	A-B TYP CB
R.506	09-10003-0A	RVC 100.0 K 0.5 W K+-10%	73138	HEL TYP 72PM
R507	12-08030-0A	RFC 4.3 K 250.0MW J+- 5%	1121	A-B TYP CB
R600	12-12862-0A	RFC 560.0 K 2.0 W 5%	1121	A-B HB
R601	12-12873-0A	RFC 560.0 K 500.0MW	1121	A-B TYPE E-B
R.602	12-08011-0A	RFC 10.0 K 250.0MW J+- 5%	1121	A-B TYP CB

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
R603	12-01138-0A	RFC 1.8 500.0MW K+-10%	1121	A-B TYP EB
R604	09-10146-0A	RVF 25.0 K 500.0MW TRIMPOT	73138	HELIPOT 72PM
R605	09-10146-0A	RVF 25.0 K 500.0MW TRIMPOT	73138	HELIPOT 72PM
R606	09-10107-0A	RVF 200.0 250.0MW K CER	73138	HEL TYPE 72PM-200
R607	09-10002-0A	RVC 5.0 K 0.5 W K+-10%	73138	HEL TYP 72PM
R608	09-10001-0A	RVC 500.0 0.5 W K	73138	HEL TYP 72PM
R609	09-10092-0A	RVF 50.0 K 500.0MW KVERT MT	73138	HELIPOT 72XW 50K
R708	12-12873-0A	RFC 560.0 K 500.0MW	1121	A-B TYPE E-B
R709	12-12873-0A	RFC 560.0 K 500.0MW	1121	A-B TYPE E-B
R710	12-08021-0A	RFC 1.2 M 250.0MW J+- 5%	1121	A-B TYP CB
R803	12-12333-0A	RFF 2.21K 250.0MW F+- 1%	16299	CGW RN55D 2211 F
R804	12-12268-0A	RFF 511.0 250 MW F+-1%	16299	CGW RN55D 5110 F
R900	12-13055-0A	RFC 3.3 500.0MW J	112	AB TYPE EB
R901	12-12333-0A	RFF 2.21K 250.0MW F+- 1%	16299	CGW RN55D 2211 F
R902	12-12264-0A	RFF 464.0 250 MW F+-1%	16299	CGW RN55D 4640 F
R905	12-13228-0A	RFC 750 500MW +-5%	0	A-B TYPE B
RN200	13-10097-0A	RNF 3028B CURRENT SHUNT	0	CADDOCK MODEL 1787-312
RN600	13-10040-1A	RNF 3028B 14 PIN DIP 1% RES.	50423	BLI LD111 RANGE RES.
RN601	13-10042-1B	RNF 3028B 14 PIN DIP 1,5%RES	50423	BLI REV 10K,100K,560K
RN700	13-10096-1A	RNF 3028B 14 PIN DIP 5% RES	50423	BLI DISPLAY RES NETWORK
RN701	13-10094-0A	RNF 680HM 14PIN DIP 7 RES	0	BECKMAN 899-3-R68
T800	20-10029-1D	TRX 3028A DC/DC CONVTR	50423	
T900	20-10054-1Q	TRX 3038A POWER	50423	BLI IEC 9V BRIDGE .6
U300	24-10212-0A	ICP CA3140E FET OP AM MINDIP	86684	RCA CA3140G FET OPAMP MINI
U400	24-10213-0A	ICP LM318N/NATJG-P/TI F.OPAM	27014	NAT SEMI DUAL IN LIN 8 PIN
U500	24-10212-0A	ICP CA3140E FET Op AM MINDIP	86684	RCA CA3140G FET OpAMp MINI
U600	24-10202-1A	ICP LD111A MODIFIED DVM .03%	50423	SILICONIX ANALOG
U700	24-10094-1A	ICP DVM DIGITAL 3 1/2 DIGIT	17856	SILICONIX LD110 MODIFIED
U701	24-10188-0A	ICP 9667 7 DARLINGTON DRIVE	7263	FAIRCHILD 9667PC
U702	24-10186-0A	ICP 74C48 7 SEGMENT DRIVE	0	NATIONAL MM74048N
U703	24-10357-0A	ICP CD4049UB UNBUFFERED	0	RCA CD4049UB
U900	24-10153-0A	ICP UA7805 5V REG.	7263	FCH UGH7805393
Y700	04-10020-0A	CRS 20.48 KHZ 0.05%	0	STATEK CX-1H-20.48/H101 C

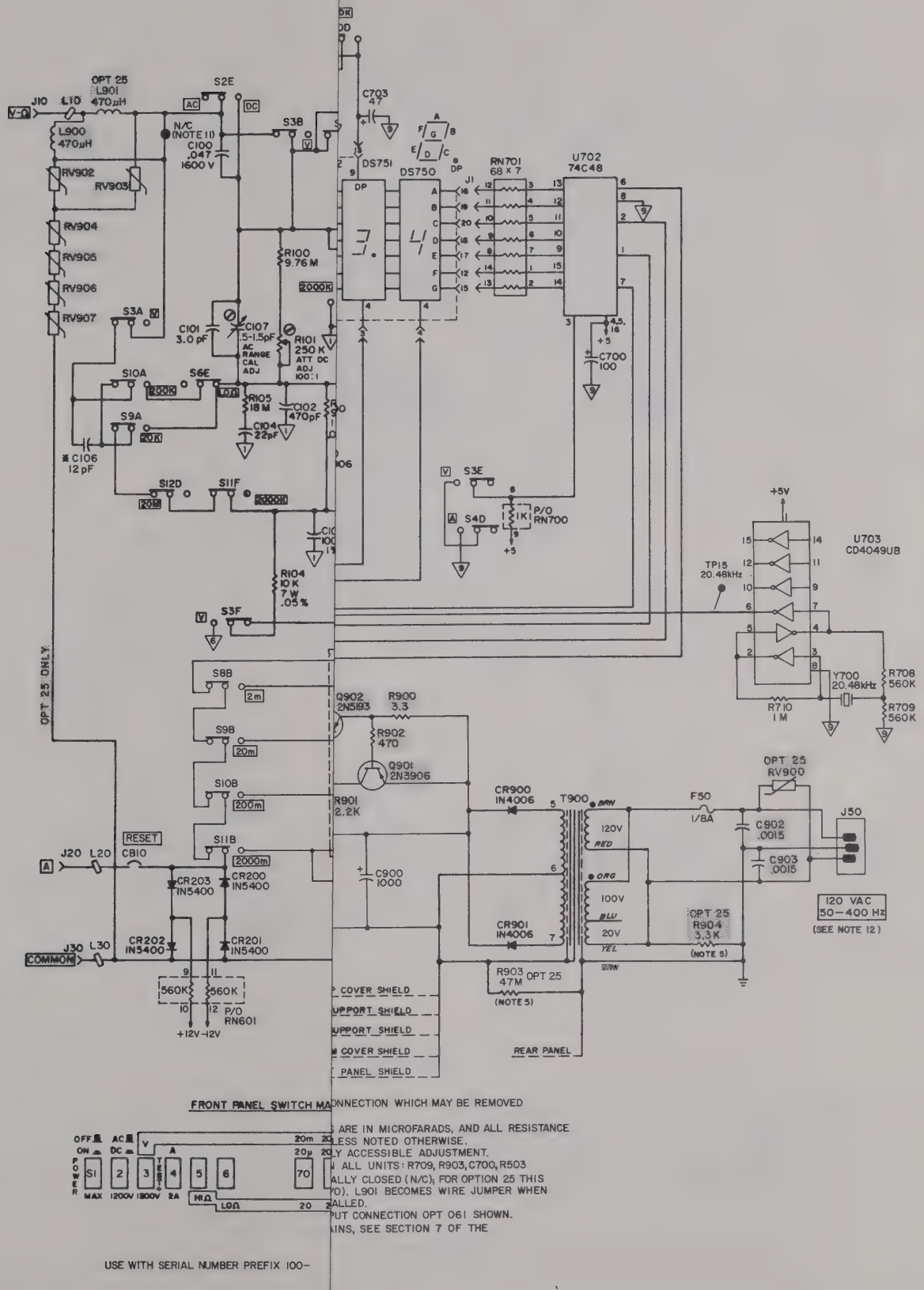
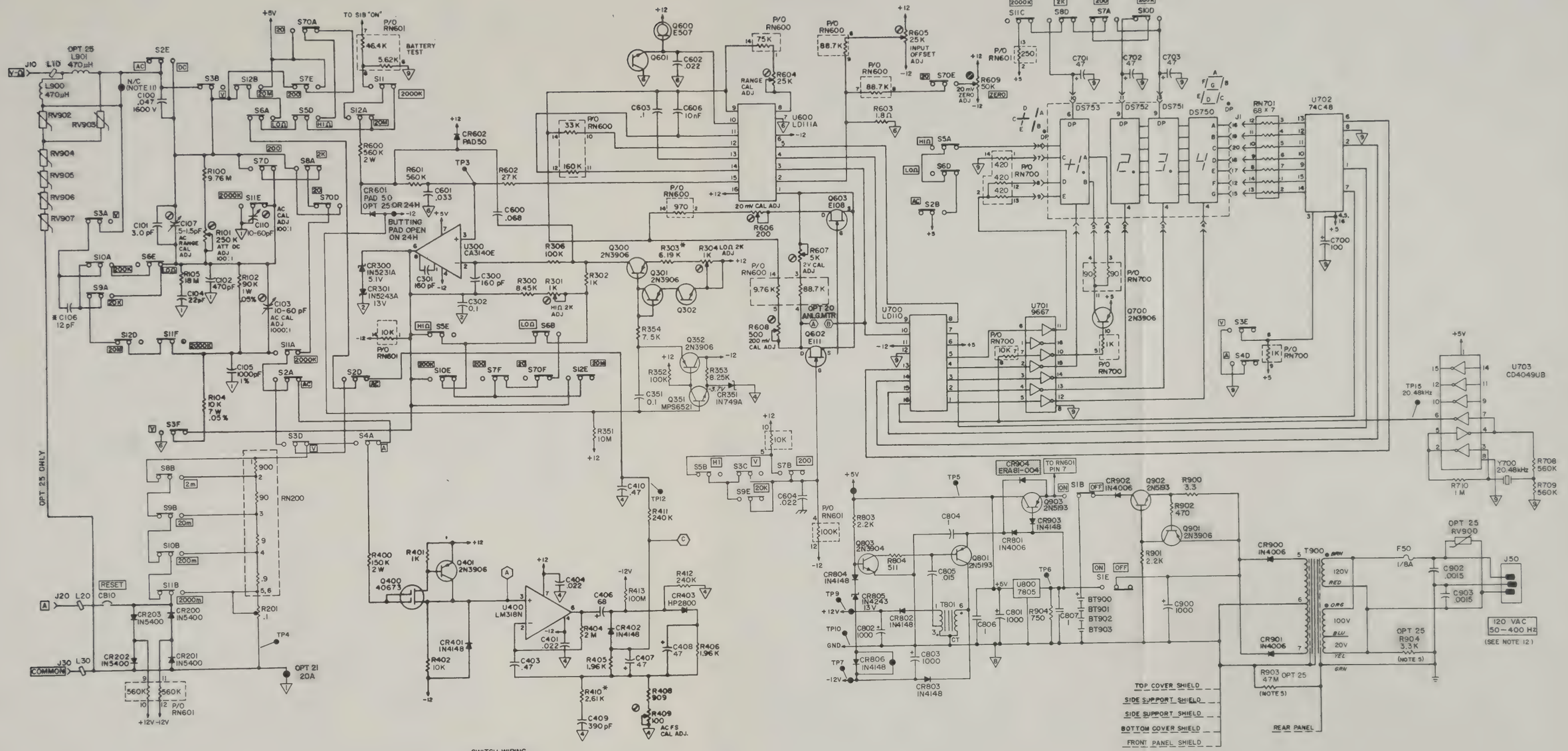
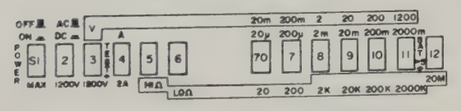


Figure 6-1. Model 3028B, Schematic Diagram
Serial Prefix 080-

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
R603	12-01138-0A	RFC 1.8 500.0MW K+-10%	1121	A-B TYP EB
R604	09-10146-0A	RVF 25.0 K 500.0MW TRIMPOT	73138	HELIPOT 72PM
R605	09-10146-0A	RVF 25.0 K 500.0MW TRIMPOT	73138	HELIPOT 72PM
R606	09-10107-0A	RVF 200.0 250.0MW K CER	73138	HEL TYPE 72PM-200
R607	09-10002-0A	RVC 5.0 K 0.5 W K+-10%	73138	HEL TYP 72PM
R608	09-10001-0A	RVC 500.0 0.5 W K	73138	HEL TYP 72PM
R609	09-10092-0A	RVF 50.0 K 500.0MW KVERT MT	73138	HELIPOT 72XW 50K
R708	12-12873-0A	RFC 560.0 K 500.0MW	1121	A-B TYPE E-B
R709	12-12873-0A	RFC 560.0 K 500.0MW	1121	A-B TYPE E-B
R710	12-08021-0A	RFC 1.2 M 250.0MW J+- 5%	1121	A-B TYP CB
R803	12-12333-0A	RFF 2.21K 250.0MW F+- 1%	16299	CGW RN55D 2211 F
R804	12-12268-0A	RFF 511.0 250 MW F+-1%	16299	CGW RN55D 5110 F
R900	12-13055-0A	RFC 3.3 500.0MW J	112	AB TYPE EB
R901	12-12333-0A	RFF 2.21K 250.0MW F+- 1%	16299	CGW RN55D 2211 F
R902	12-12264-0A	RFF 464.0 250 MW F+-1%	16299	CGW RN55D 4640 F
R905	12-13228-0A	RFC 750 500MW +-5%	0	A-B TYPE B
RN200	13-10097-0A	RNF 3028B CURRENT SHUNT	0	CADDOCK MODEL 1787-312
RN600	13-10040-1A	RNF 3028B 14 PIN DIP 1% RES.	50423	BLI LD111 RANGE RES.
RN601	13-10042-1B	RNF 3028B 14 PIN DIP 1,5%RES	50423	BLI REV 10K,100K,560K
RN700	13-10096-1A	RNF 3028B 14 PIN DIP 5% RES	50423	BLI DISPLAY RES NETWORK
RN701	13-10094-0A	RNF 680HM 14PIN DIP 7 RES	0	BECKMAN 899-3-R68
T800	20-10029-1D	TRX 3028A DC/DC CONVTR	50423	
T900	20-10054-1Q	TRX 3038A POWER	50423	BLI IEC 9V BRIDGE .6
U300	24-10212-0A	ICP CA3140E FET OP AM MINDIP	86684	RCA CA3140G FET OPAMP MINI
U400	24-10213-0A	ICP LM318N/NATJG-P/TI F.OPAM	27014	NAT SEMI DUAL IN LIN 8 PIN
U500	24-10212-0A	ICP CA3140E FET OP AM MINDIP	86684	RCA CA3140G FET OPAMP MINI
U600	24-10202-1A	ICP LD111A MODIFIED DVM .03%	50423	SILICONIX ANALOG
U700	24-10094-1A	ICP DVM DIGITAL 3 1/2 DIGIT	17856	SILICONIX LD110 MODIFIED
U701	24-10188-0A	ICP 9667 7 DARLINGTON DRIVE	7263	FAIRCHILD 9667PC
U702	24-10186-0A	ICP 74C48 7 SEGMENT DRIVE	0	NATIONAL MM74048N
U703	24-10357-0A	ICP CD4049UB UNBUFFERED	0	RCA CD4049UB
U900	24-10153-0A	ICP UA7805 5V REG.	7263	FCH UGH7805393
Y700	04-10020-0A	CRS 20.48 KHZ 0.05%	0	STATEK CX-1H-20.48/H101 C

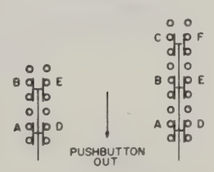


FRONT PANEL SWITCH MARKING



USE WITH SERIAL NUMBER PREFIX 100-

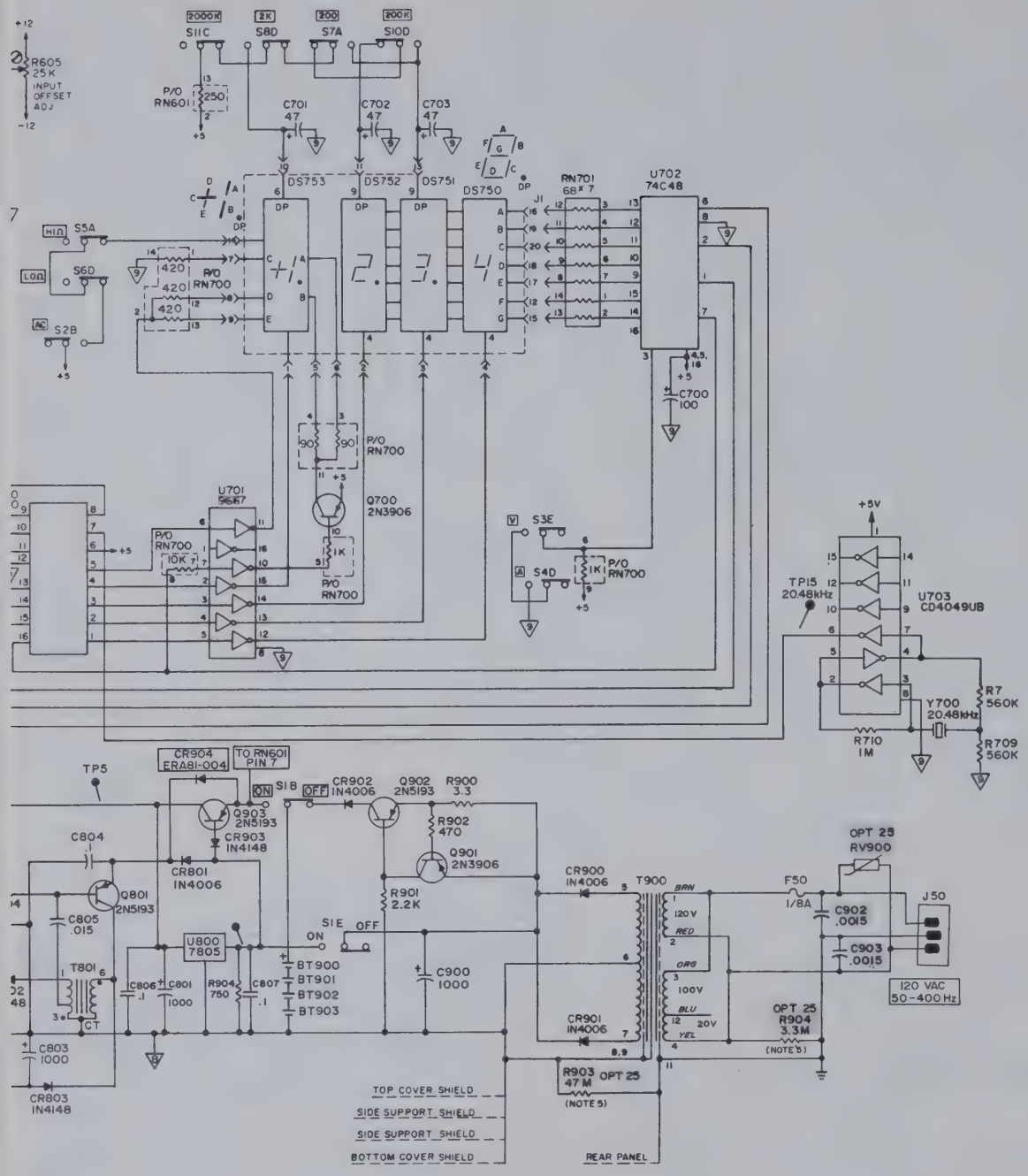
SWITCH WIRING



S1 & S2 LATCHED INDIVIDUALLY
S3,S4,S5,S6 LATCH 1 OF 4
S7,S8,S9,S10,S11,S12,S70 LATCH 1 OF 7
ALL PUSHBUTTON SWITCHES ARE SHOWN IN THE "OUT" POSITION ON THIS SCHEMATIC.

NOTES:
1. * DENOTES CALIBRATION ITEM, MOST FREQUENT VALUE SHOWN.
2. ⊘ DENOTES INTERNAL ADJUSTMENT.
3. S1 THROUGH S12 AND S70 SHOWN IN OUT POSITION.
4. □ DENOTES PANEL MARKING.
5. OPTIONAL; USED WITH HIGH-VOLTAGE PROBES FOR SAFETY PURPOSES.
6. ▽ INPUT ATTEN AC COMPENSATION GND
   ▽2 HIGH QUALITY ANALOG INPUT GND
   ▽4 AC TO DC CONV GND
   ▽6 HIGH QUALITY ANALOG TO DIGITAL CONV GND
   ▽8 PWR SUPPLY GND
   ▽9 DIGITAL GND
7. ●—● INDICATES SOLDER CONNECTION WHICH MAY BE REMOVED TO ISOLATE CIRCUIT.
8. ALL CAPACITANCE VALUES ARE IN MICROFARADS, AND ALL RESISTANCE VALUES ARE IN OHMS, UNLESS NOTED OTHERWISE.
9. ⊘ DENOTES EXTERNALLY ACCESSIBLE ADJUSTMENT.
10. PARTS NOT INSTALLED IN ALL UNITS: R709, R903, C700, R503
11. THIS CONNECTION NORMALLY CLOSED (N/C), FOR OPTION 25 THIS CONNECTION IS OPEN (N/O). L901 BECOMES WIRE JUMPER WHEN OPTION 25 IS NOT INSTALLED.
12. 120 VOLT AC POWER INPUT CONNECTION OPT 061 SHOWN. FOR 100, 220, OR 240 MAINS, SEE SECTION 7 OF THE INSTRUCTION MANUAL.

Figure 6-1. Model 3028B, Schematic Diagram
Serial Prefix 080-



JENT VALUE SHOWN.

OSITION.

:S FOR SAFETY PURPOSES.

GND

MAY BE REMOVED TO

ADS AND ALL RESISTANCE
MISE.

9. THIS CONNECTION NORMALLY CLOSED (N/C). FOR OPTION 25 THIS CONNECTION IS OPEN(N/O). L901 BECOMES A WIRE JUMPER WHEN OPTION 25 IS NOT INSTALLED.
10. 120 VOLT AC POWER INPUT CONNECTION OPT 061 SHOWN. FOR 100, 220, OR 240 VOLT MAINS SEE SECTION 7 OF THE INSTRUCTION MANUAL.

Figure 6-2. Model 3028B, Option 24, Schematic Diagram, Serial Prefix 080-

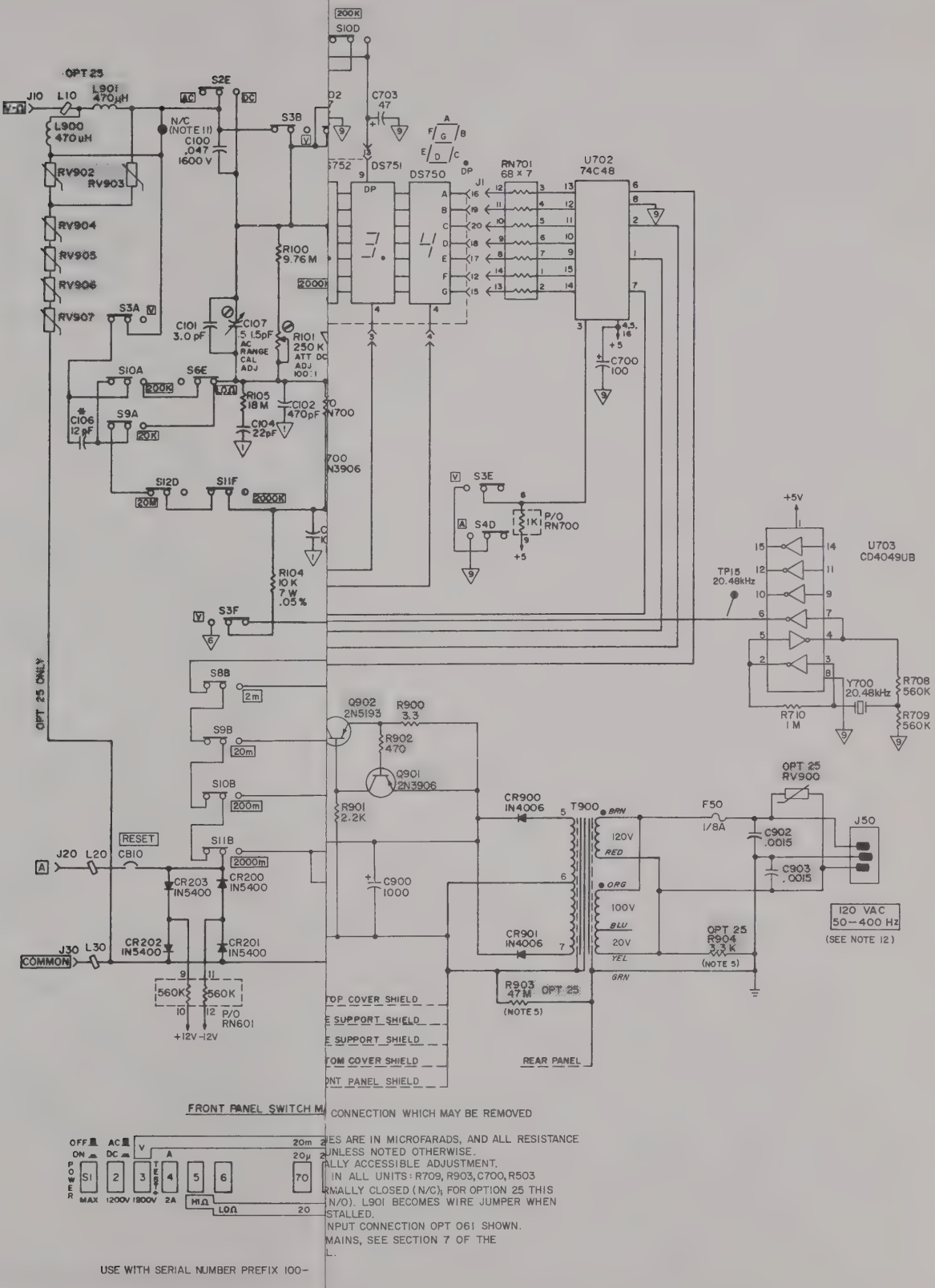
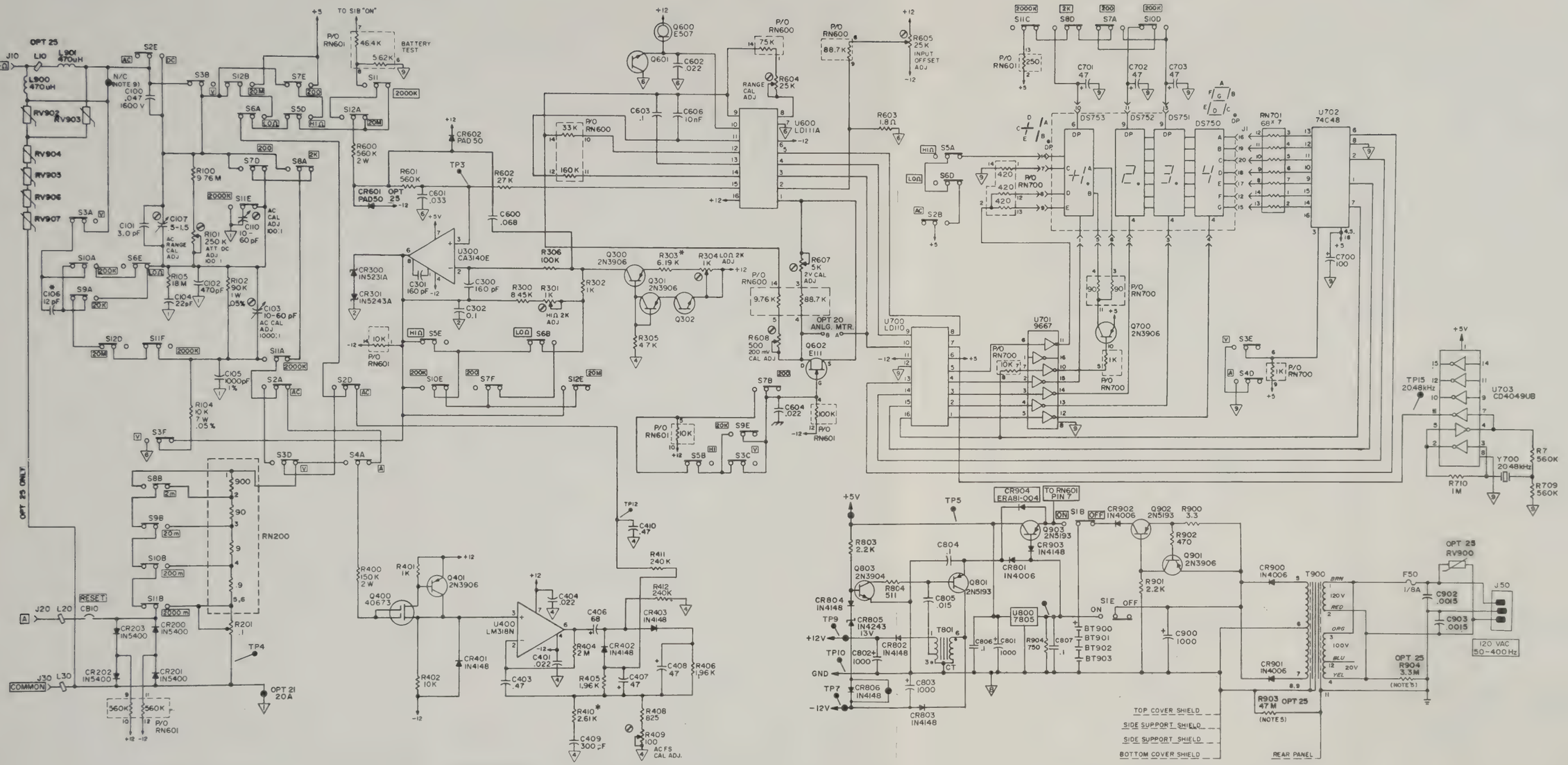
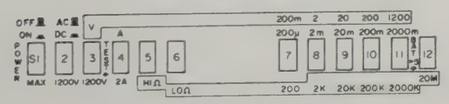


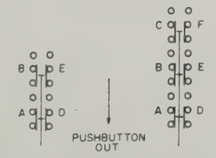
Figure 6-3. Model 3028B, Option 24H, Schematic Diagram, Serial Prefix 080-



FRONT PANEL SWITCH MARKING



SWITCH WIRING

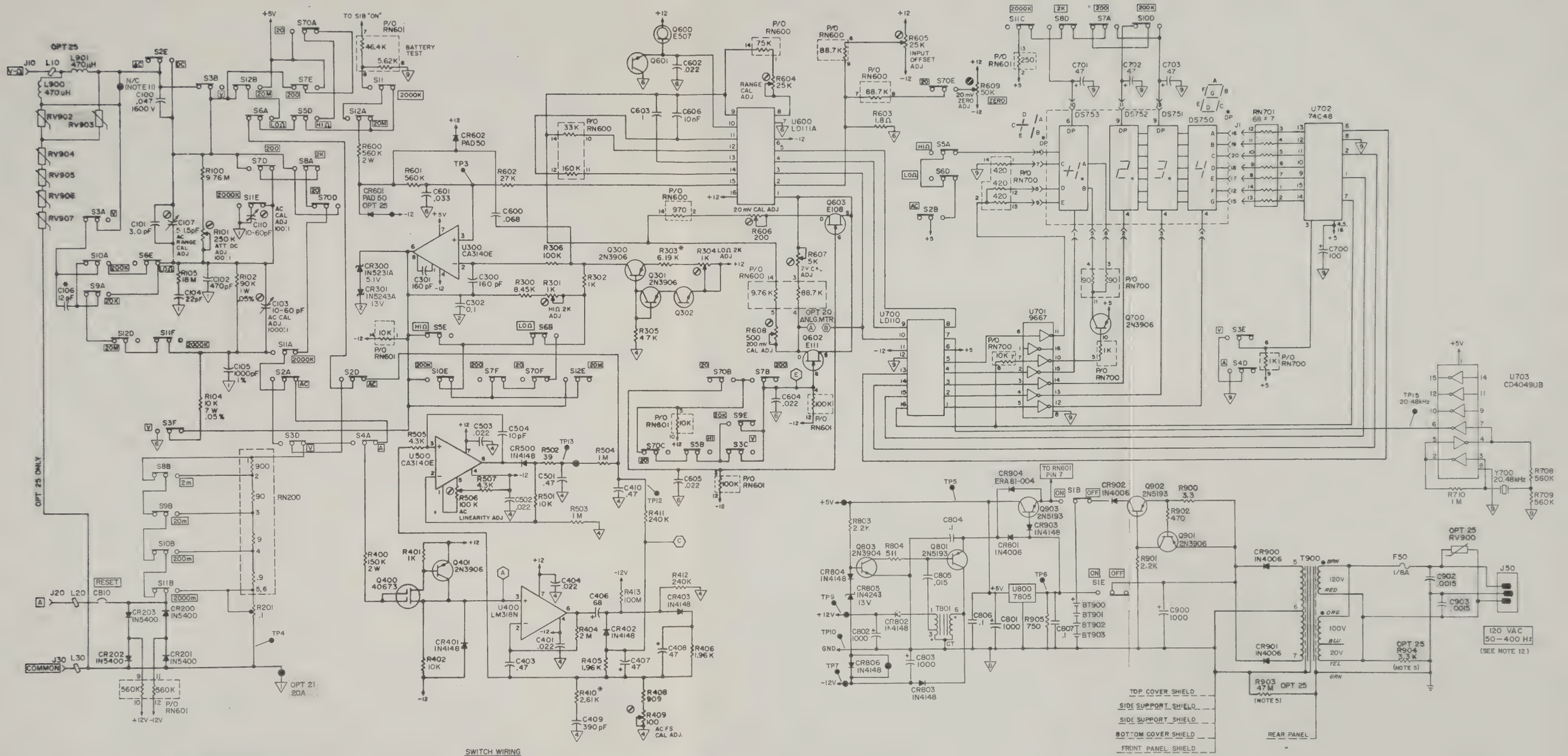


S1 & S2 LATCHED INDIVIDUALLY
S3,S4,S5,S6 LATCH 1 OF 4
S7,S8,S9,S10,S11,S12 LATCH 1 OF 6

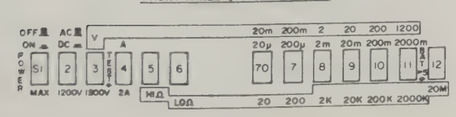
NOTES:

1. * DENOTES CALIBRATION ITEM, MOST FREQUENT VALUE SHOWN.
2. ⊘ DENOTES INTERNAL ADJUSTMENT.
3. S1 THROUGH S12 AND S70 SHOWN IN OUT POSITION.
4. ▭ DENOTES PANEL MARKING.
5. OPTIONAL; USED WITH HIGH-VOLTAGE PROBES FOR SAFETY PURPOSES.
6. ▽1 INPUT ATTEN AC COMPENSATION GND
   ▽2 HIGH QUALITY ANALOG INPUT GND
   ▽4 AC TO DC CONV GND
   ▽6 HIGH QUALITY ANALOG TO DIGITAL CONV GND
   ▽8 PWR SUPPLY GND
   ▽9 DIGITAL GND
7. —● INDICATES SOLDER CONNECTION WHICH MAY BE REMOVED TO ISOLATE CIRCUIT.
8. ALL CAPACITANCE VALUES ARE IN MICROFARADS AND ALL RESISTANCE VALUES ARE IN OHMS UNLESS NOTED OTHERWISE.
9. THIS CONNECTION NORMALLY CLOSED (N/C), FOR OPTION 25 THIS CONNECTION IS OPEN(N/O). L901 BECOMES A WIRE JUMPER WHEN OPTION 25 IS NOT INSTALLED.
10. 120 VOLT AC POWER INPUT CONNECTION OPT 061 SHOWN. FOR 100, 220, OR 240 VOLT MAINS SEE SECTION 7 OF THE INSTRUCTION MANUAL.

Figure 6-2. Model 3028B, Option 24, Schematic Diagram, Serial Prefix 080-

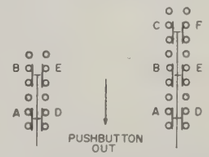


FRONT PANEL SWITCH MARKING



USE WITH SERIAL NUMBER PREFIX 100-

SWITCH WIRING



S1 & S2 LATCHED INDIVIDUALLY
S3, S4, S5, S6 LATCH 1 OF 4
S7, S8, S9, S10, S11, S12, S70 LATCH 1 OF 7
ALL PUSHBUTTON SWITCHES ARE SHOWN IN THE "OUT" POSITION ON THIS SCHEMATIC.

NOTES:
1. * DENOTES CALIBRATION ITEM, MOST FREQUENT VALUE SHOWN.
2. ⊘ DENOTES INTERNAL ADJUSTMENT.
3. S1 THROUGH S12 AND S70 SHOWN IN OUT POSITION.
4. □ DENOTES PANEL MARKING.
5. OPTIONAL; USED WITH HIGH-VOLTAGE PROBES FOR SAFETY PURPOSES.
6. ▽ (7) INPUT ATTEN AC COMPENSATION GND
   (2) HIGH QUALITY ANALOG INPUT GND
   (4) AC TO DC CONV GND
   (5) HIGH QUALITY ANALOG TO DIGITAL CONV GND
   (6) PWR SUPPLY GND
   (9) DIGITAL GND
7. ●— INDICATES SOLDER CONNECTION WHICH MAY BE REMOVED TO ISOLATE CIRCUIT.
8. ALL CAPACITANCE VALUES ARE IN MICROFARADS, AND ALL RESISTANCE VALUES ARE IN OHMS, UNLESS NOTED OTHERWISE.
9. ⊘ DENOTES EXTERNALLY ACCESSIBLE ADJUSTMENT.
10. PARTS NOT INSTALLED IN ALL UNITS R709, R903, C700, R503
11. THIS CONNECTION NORMALLY CLOSED (N/C); FOR OPTION 25 THIS CONNECTION IS OPEN (N/O). L901 BECOMES WIRE JUMPER WHEN OPTION 25 IS NOT INSTALLED.
12. 120 VOLT AC POWER INPUT CONNECTION OPT 061 SHOWN. FOR 100, 220, OR 240 MAINS, SEE SECTION 7 OF THE INSTRUCTION MANUAL.

Figure 6-3. Model 3028B, Option 24H, Schematic Diagram, Serial Prefix 080-

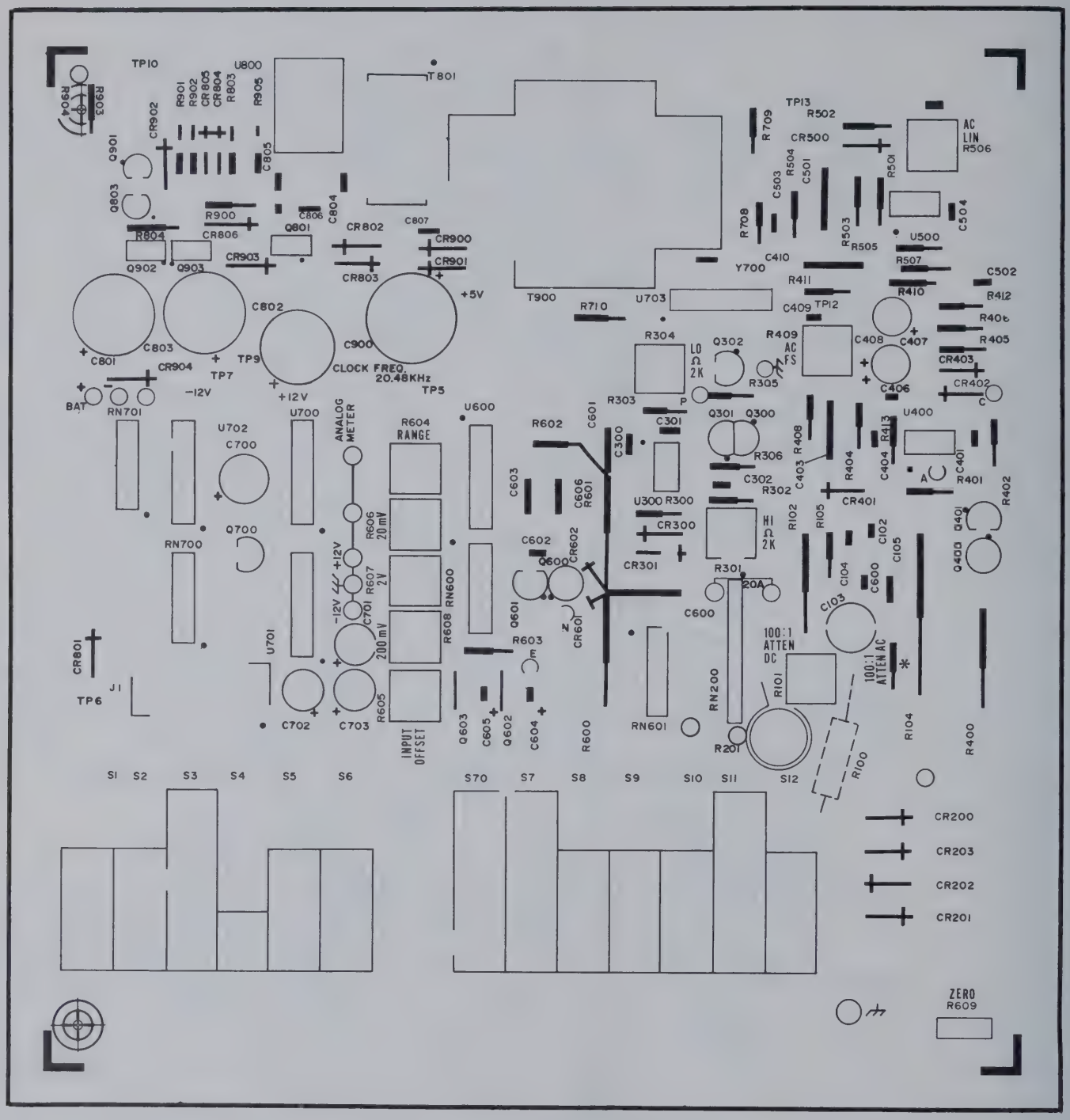
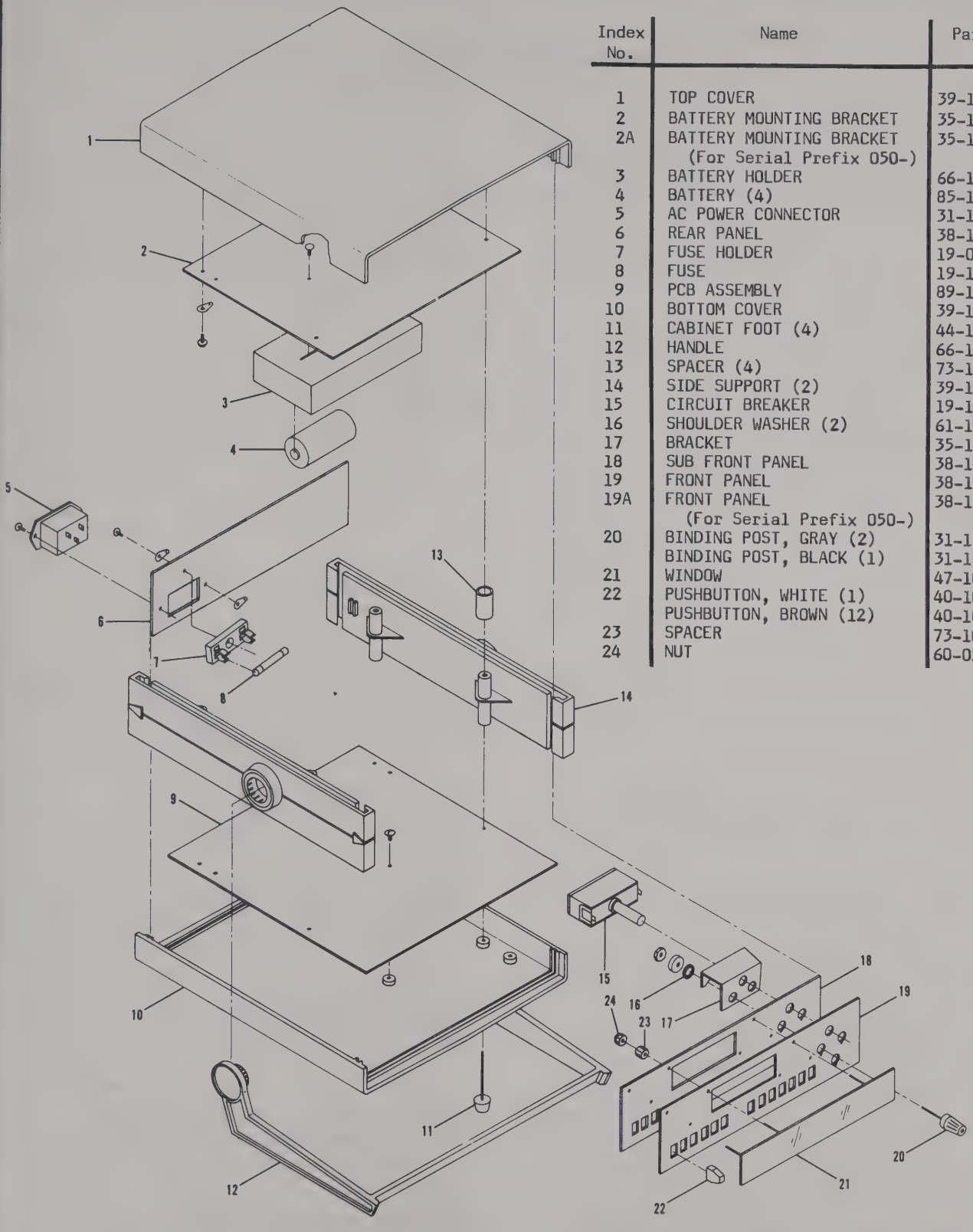


Figure 6-4. Model 3028B, Parts Location Diagram



Index No.	Name	Part No.
1	TOP COVER	39-10016-1S
2	BATTERY MOUNTING BRACKET	35-10146-1L
2A	BATTERY MOUNTING BRACKET (For Serial Prefix 050-)	35-10146-10
3	BATTERY HOLDER	66-10017-0A
4	BATTERY (4)	85-10059-0A
5	AC POWER CONNECTOR	31-10000-0A
6	REAR PANEL	38-10147-1F
7	FUSE HOLDER	19-09500-0A
8	FUSE	19-10036-0A
9	PCB ASSEMBLY	89-10551-1A
10	BOTTOM COVER	39-10017-1S
11	CABINET FOOT (4)	44-10012-0A
12	HANDLE	66-10008-1S
13	SPACER (4)	73-10067-1A
14	SIDE SUPPORT (2)	39-10018-3S
15	CIRCUIT BREAKER	19-10035-1E
16	SHOULDER WASHER (2)	61-10027-0A
17	BRACKET	35-10093-1K
18	SUB FRONT PANEL	38-10152-1L
19	FRONT PANEL	38-10140-1L
19A	FRONT PANEL (For Serial Prefix 050-)	38-10233-1L
20	BINDING POST, GRAY (2)	31-10132-0A
	BINDING POST, BLACK (1)	31-10133-0A
21	WINDOW	47-10038-1F
22	PUSHBUTTON, WHITE (1)	40-10056-1M
	PUSHBUTTON, BROWN (12)	40-10049-1M
23	SPACER	73-10064-0A
24	NUT	60-05708-0A

Figure 6-5. Model 3028B, Case Assembly, Exploded View

SECTION 7
OPTIONS AND ACCESSORIES

7–1. INTRODUCTION.

7–2. This section contains information for the options and accessories which can be used with the Model 3028B Digital Multimeter. Each option and accessory is described individually. Where applicable, field installation procedures, operating and maintenance instructions, a replaceable parts list, and a schematic diagram are included.

7–3. PARALLEL BCD PRINTER OUTPUT, OPTION 01.

7–4. General. The BCD output option provides digital measurement information in parallel BCD format to a rear-panel connector for use with digital printers, systems, limit controllers, and other remote applications.

7–5. Specifications.

Type: Serial to parallel converter.

Logic: Positive true.

Form: Four-line BCD 1-2-4-8.
TTL compatible. Buffered for fan-out of two.
"1" = +3.5 V dc to 5.7 V dc.
"0" = 0 to 0.4 V dc.

Data Output Update Command: By "0" state of negative-going input pulse 10 μs, or contact closure to digital common. New measurements made after pulse will be displayed but will not appear at BCD outputs. Maximum allowable update command rate, three per second.

Continuous Data Output Update Command: By holding "0" state, the BCD output is updated at an internal trigger rate of typically four per second.

Busy Flag (Printer Inhibit): "1" state at Busy Flag output signifies BCD output in process of updating. During this interval, all Data Update command pulses from printer are ignored. "0" state signifies not Busy. Busy Flag internally modifiable to Ready.

Data Output "Pullup" Voltage: Normally "1" state (+5 V dc). Internal pullup through 15 kΩ. Modifiable to +12 V.

7–6. Operation.

7–7. *Input/Output Data.* The input/output data available at the rear-panel connector J1200 is listed in Table 7–1. The pin assignments and the logic level requirements are also listed.

7–8. *Data Update Input.* The BCD output may be updated by either a Data Update pulse or a Continuous Update command. This feature operates as the conventional "inhibit" signal. The Data Update pulse at pin 23 must be a negative-going pulse having a width greater than 10 μs. Measurement data accumulated after a Data Update pulse is received will not appear at the BCD output connector J1200, but the new data will be displayed. The maximum allowable rate of data update is three per second. The Continuous Update command at pin 24, when held, will cause the BCD output to be updated at the DMM display, multiplex refresh rate of approximately four per second.

7–9. *Busy Flag Output.* The time period of actual updating of the BCD output serial-to-parallel converter is signified by a Busy Flag output at pin 22 of the BCD output connector, J1200. During this period all external update pulses are locked out and therefore ignored. A signal low shows not Busy. This feature operates as the conventional "print" command. A simple modification on the BCD output printed circuit board assembly permits the Busy Flag logic to be inverted and thereby used as a Ready Flag. A signal high on pin 22 will then show that the BCD output is ready for update. A signal low indicates not Ready since the serial-to-parallel converter is being updated by the counter. To modify the Busy Flag, proceed as follows:

1. Disconnect the power cord.
2. Remove the top cover of the instrument case. Refer to paragraph 5–33.
3. Locate S1200 (a wire link switch near U1206) on the BCD output assembly.
4. Refer to the BCD schematic, Figure 7–1, and remove jumper wire S1200-1, 3.
5. Install the jumper wire as S1200-1, 2 to provide a Ready Flag.
6. Replace the top cover and reconnect the power cord.

7–10. *Data Output Pullup Voltage.* The BCD output data lines are normally pulled up through 15 kΩ resistors to the +5 V dc supply of the counter. A simple jumper modification at S1201 on the BCD output assembly permits an external pullup voltage (+5.7 V dc maximum) to be applied at pin 25 of the BCD output connector, J1200. To modify the unit to incorporate the external pullup feature, proceed as follows:

1. Disconnect the power cord.
2. Remove the top cover of the instrument case. Refer to paragraph 5–33.
3. Locate S1202 (a wire link switch) on the BCD output assembly.
4. Refer to the BCD schematic, Figure 7–1, and remove jumper wire S1201-4, 5 to disconnect the referral +5-volt supply.

TABLE 7–1. DIGITAL INPUT/OUTPUT DATA AT CONNECTOR J1200

	Signal	Signal Logic		Logic Level	
		High	Low	"1"	"0"
1	Least Significant Digit	1	0	4.3 V to 5.7 V	0 to +0.4 V
2		2	0		
26		4	0		
27		8	0		
3	2nd Digit from LSD	1	0		
4		2	0		
28		4	0		
29		8	0		
5	3rd Digit from LSD	1	0		
6		2	0		
30		4	0		
30		8	0		
7	4th Digit from LSD	1	0		
8		2	0		
32		4	0		
33		8	0		
19	Decimal Point 1 (right)	On	–		
44	Decimal point 2	On	–		
45	Decimal point 3	On	–		
20	Circuit ground and Logic COMMON				
22	Busy Flag (Output)	Busy	Not Busy		
23	Data Update Pulse (Input)	Update	(pulse)		
24	Continuous Update (Input)	Update			0 to +0.4 V dc or contact closure to logic COMMON
48	Overrange	–	Overrange	Open or +5 V dc	
25	External Pull Up (+12V)	–	–		
47	+5 Volt Reference (1 mA Max)				
50	Case ground (earth)				

5. Install the jumper wire from S1201-4 to J1200-25 to provide the external pullup voltage connection. Carefully solder the wire in place.

6. Replace the top cover and reconnect the power cord.

7–11. *BCD Output Cable.* A six-foot long BCD output cable with mating 50-pin Blue Ribbon connectors (Ballantine Model 12253A) is available as an option.

7–12. Theory of Operation. The BCD printer output option is basically a serial-to-parallel converter with associated control circuitry. It processes the serial output data from U700 in the 3028B into parallel BCD format. Four Type D MOS flip-flops in U1201, U1202, U1203, and U1204 are the storage registers which convert digit strobes D1, D2, D3, and D4; sequent strobes B1, B2, B3, and B4; and the polarity sign data. AND gates in U1204 control the update of the storage registers. A schematic diagram is shown in Figure 7–1.

7–13. Update may be continuous at the multiplexing rate of the 3028B or commanded by pulsing the data update line. Flip-flops in U1206 store this information and provide coincidence signals to the AND gates of U1205. New data is loaded into the storage register when the clock pulse is synchronized with the digit strobes.

7–14. "D" flip-flops in U1200, U1201, U1202, U1203, and U1204 provide buffered output to drive several TTL loads. Decimal points and the polarity sign are buffered by hex inverter U1210.

7–15. The Busy Flag (or Ready Flag) output signal is provided by U1206 to indicate the state of readiness of the information in the storage registers. The Busy Flag drops to "0" indicating the completion of the data update sequence.

7–16. U1209 is a four-input coincidence detector which senses the simultaneous existence of all four digit strobes. This is the "flashing" overrange signal of the 3028B. The output of U1209 is processed by flip-flops in U1208 which holds the overrange data available at J1200.

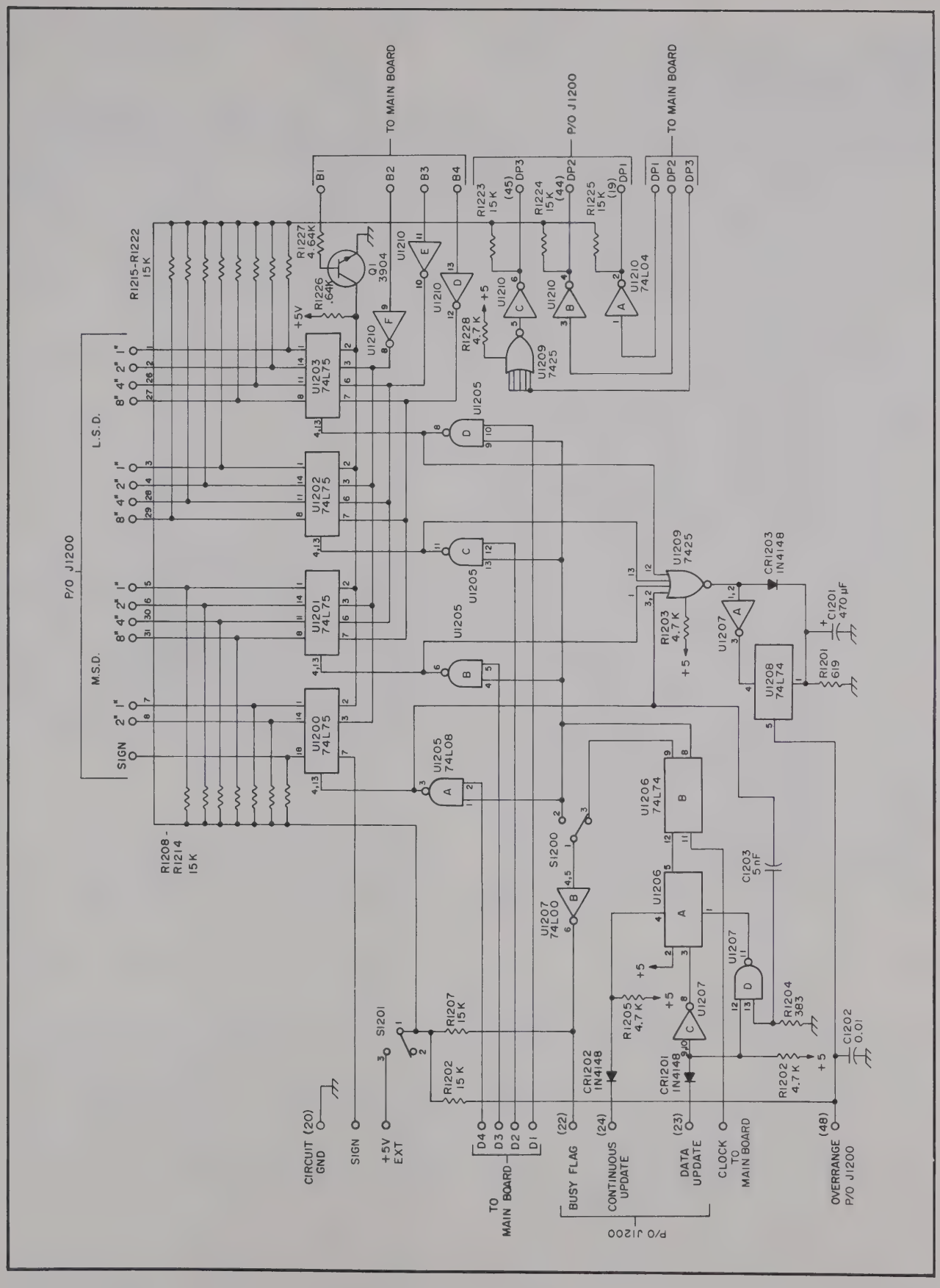


Figure 7–1. BCD Schematic Diagram

TABLE 7–2. PARTS LIST, BCD PRINTER OUTPUT, OPTION 01

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
C 1201	07100910A	CEA 470.0UF 6.3 V UPPC MNT		STETNER TRUSH FRO EK470/6
C 1202	07102340A	CCD 10. NF 100. VM	56289	SPRAGUE TG-S10 OR EQUAL
C 1203	07025400A	CCD 5.0NF 100.0 V +-20%	04171	ARCO #TCPR005 OR EQUAL
CR 1201	05100490A	DGP 1N4148 100 10M	01295	TI SI D035 4 5 JAN
CR 1202	05100490A	DGP 1N4148 100 10M	01295	TI SI D035 4 5 JAN
CR 1203	05100490A	DGP 1N4148 100 10M	01295	TI SI D035 4 5 JAN
R 1201	12122760A	RFF 619.0 250.0MW FT- 1%	16299	CGW RN55D 6190 F
R 1202	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1203	12123640A	RFF 4.64K 250.0MW FT- 1%	16299	CGW RN55D 4641 F
R 1204	12122560A	RFF 383.0 250.0MW FT- 1%	16299	CGW RN55D 3830 F
R 1205	12123640A	RFF 4.64K 250.0MW FT- 1%	16299	CGW RN55D 4641 F
R 1206	12123640A	RFF 4.64K 250.0MW FT- 1%	16299	CGW RN55D 4641 F
R 1208	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1209	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1210	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1211	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1212	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1213	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1214	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1215	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1216	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1217	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1218	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1219	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1220	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1221	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1222	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1223	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1224	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1225	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1226	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1227	12124170A	RFF 15.0 K 250.0MW FT- 1%	16299	CGW RN55D 1502 F
R 1228	12123640A	RFF 4.64K 250.0MW FT- 1%	16299	CGW RN55D 4641 F
U 1200	24101410A	ICP 74LS75 QUAD LATCH 16 DIP	01295	TI
U 1201	24101410A	ICP 74LS75 QUAD LATCH 16 DIP	01295	TI
U 1202	24101410A	ICP 74LS75 QUAD LATCH 16 DIP	01295	TI
U 1204	24101410A	ICP 74LS75 QUAD LATCH 16 DIP	01295	TI
U 1205	24101440A	ICP 74LS08 QUAD AND 14 DIP	01295	TI
U 1206	24101430A	ICP 74LS74 D FIFL 14 DIP	01295	TI
U 1207	24101450A	ICP 74LS00 QUAD NAND 14 DIP	01295	TI
U 1208	24101430A	ICP 74LS74 D FIFL 14 DIP	01295	TI
U 1209	24101460A	ICP 74S260 DUAL NOR 14 DIP	01295	TI
U 1210	24101420A	ICP 74LS04 HEX INV 14 DIP	01295	TI

7–17. INTERNAL RECHARGEABLE BATTERY, OPTION 05.

7–18. General. Option 05 equips the Model 3028B with four rechargeable nickel-cadmium batteries, installed as shown in Figure 7–2, which can be used in place of ac power to operate the instrument. The optional battery connections and the charger circuit are shown in Figure 6–1. The batteries are recharged by setting the POWER switch S1 to OFF and connecting the ac power to the instrument.

7–19. Specifications.

Continuous Operation: 5 hours (20°C to 30°C)

Charge Time: 16 hours (15°C to 35°C)

Battery Life: 350 to 500 charge-discharge cycles

Battery Type: Four NiCad "C" cells

7–20. Operation. When the batteries are fully charged, the Model 3028B may be disconnected from the ac power line and operated for more than 5 hours. The battery-charge condition may be checked by disconnecting the ac power and pushing in the POWER (S1), V (S3), 2000k (S11), and 20M (S12) pushbuttons. A display reading greater than 500 indicates that the batteries are charged. Fully charged batteries will indicate above 535.

Note

It is recommended that NiCad batteries be recharged at least every 90 days and that they be stored where the temperature is below +30°C (+86°F).

Note

The NICAD batteries should be periodically deep discharged (BAT TEST display reading below 480) and then fully recharged. This avoids battery memory which limits charge capacity and instrument operating time.

For additional information and the theory of operation, refer to paragraphs 3–9, 3–10, 4–50, 4–51, and 4–52.

7–21. Installation. Battery Option 05 is easily installed in the field. Remove the covers of the instrument (refer to paragraph 5–33). Attach and secure the battery holder and the mounting plate to the underside of the top cover with the screws supplied; install the terminal lug under the right screw. Solder the blue lead to the terminal lug and to the instrument ground. Solder the battery red lead to the + terminal and the black lead to the – terminal, located at the rear left corner of the main printed wiring assembly.

* Install and solder lamp DS900 and resistor R900 in the holes provided in the printed wiring assembly (just to the left of the + and – terminals). Replace F50 with a 1/8-ampere, slow-blow fuse.

7–22. With the ac power cord connected, but with the POWER switch OFF, allow the batteries to charge for 16 hours.* Note that DS900 lights. After the batteries are charged, check the battery-power operation of the instrument. Check the battery charge as instructed in paragraph 7–20. Replace the top and bottom covers.

7–23. Battery Replacement. Remove the top cover of the instrument (refer to paragraph 5–33). Remove the old batteries. Note the polarity markings in the holder and install four new batteries (Battery Kit P/N 89-10422-1A). Check the battery charge as described in paragraph 7–20 and recharge if necessary.* Check the charging mode by noting that DS900 lights. Replace cover and attaching hardware.

TABLE 7–3. PARTS LIST, INTERNAL RECHARGEABLE BATTERY, OPTION 05

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
BT 900	85100590A	BNC C NICK-CAD 1.5AH	09823	GOULD
BT 901	85100590A	BNC C NICK-CAD 1.5AH	09823	GOULD
BT 902	85100590A	BNC C NICK-CAD 1.5AH	09823	GOULD
BT 903	85100590A	BNC C NICK-CAD 1.5AH	09823	GOULD

* Applies only to units with serial prefix 050- and below.

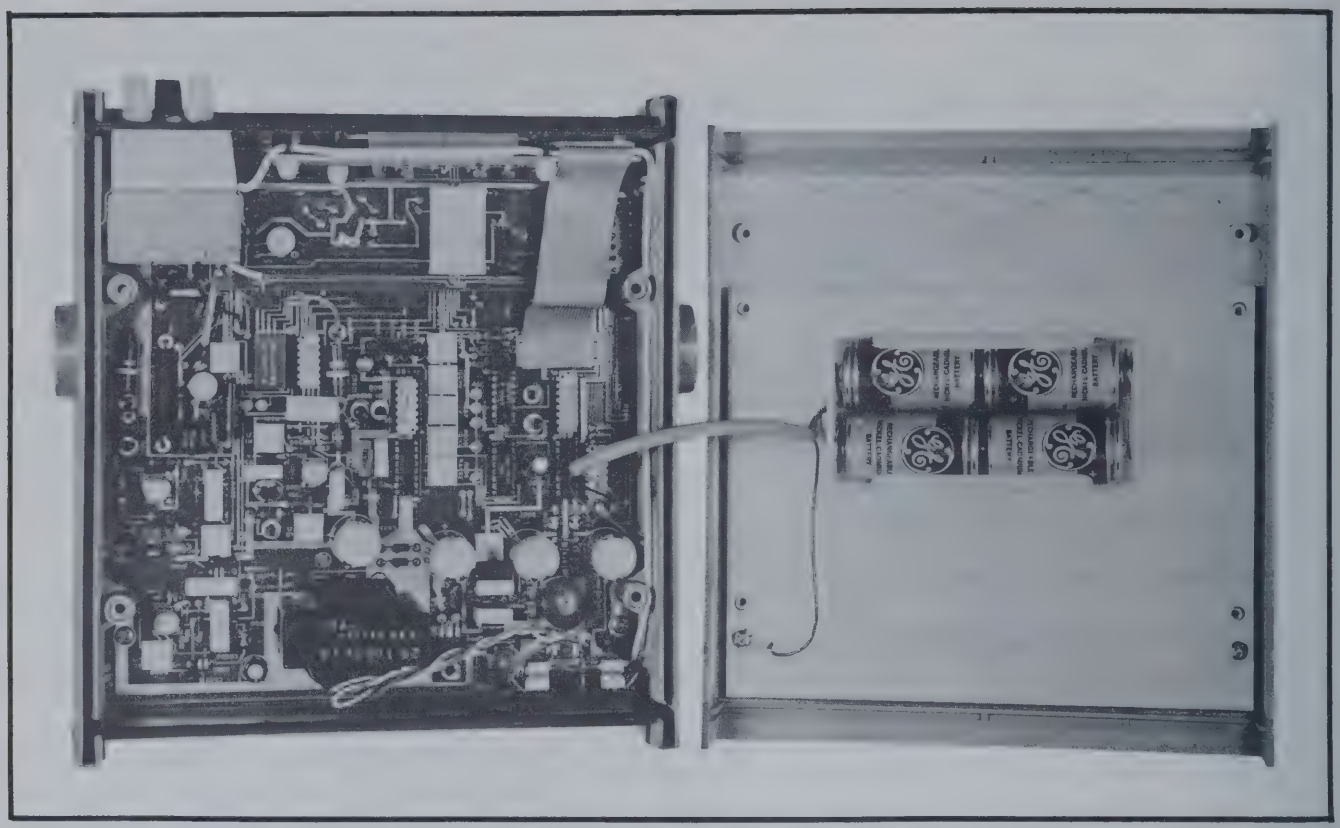


Figure 7–2. Battery Option 05 Installed

7–24. UNIVERSAL AC POWER VOLTAGE, OPTION 06.

7–25. General. The standard Model 3028B is supplied for operation with nominal 120-volt, 48- to 440-Hz ac power. Option 06 provides a universal power transformer (P/N 20-10054-1) with an IEC multi-tap primary so that the 3028B may be operated with other standard ac power sources.

7–26. Specifications. The multi-tap primary of the transformer supplied with Option 06 may be wired for any one of the ac voltages listed in the following table; the subordinate option numbers are included for identification.

Option	Nominal	Range	Frequency
060	100 V	86 to 108 V	48 to 440 Hz
061	120 V	103 to 130 V	48 to 440 Hz
062	220 V	196 to 245 V	48 to 440 Hz
063	240 V	208 to 260 V	48 to 440 Hz

7–27. Installation. Check that the rear panel does not specify the operating line voltage required. Remove the top cover (refer to paragraph 5–33). Check that the power transformer T900 has only three wire leads and is marked 20-10031-1. Remove the bottom cover. Use a 35-watt soldering iron and a solder sipper to remove the solder from the retaining tabs of T900 and from the six terminals. Remove the transformer and replace it with the universal power transformer P/N 20-10054-1, making sure that the five wire leads are toward the rear panel. Carefully fold over the transformer retaining tabs. Solder the six terminals and the tabs with 60/40 rosin core solder. Clean off all flux residue.

7–28. Connections for Transformer Primary. The power transformer primary connections for the different ac input voltages specified in paragraph 7–26 are shown in Figure 7–3.

7–29. Installation Precautions. Be sure to solder all connections carefully. Twist all wires tightly together. Carefully tape exposed joined leads with electrical tape and seal with plastic shrink tubing so that no wiring is exposed. Dress all wires away from components and circuit ground on the printed wiring assembly board or top cover.

7–30. After all modification wiring has been completed, connect the 3028B to a line Variac, or similar device, which is set to zero output. Slowly increase the voltage to the 3028B and observe that it functions properly. If desired, check the unregulated +5 volts dc at TP5 to check that approximately 9.4 volts appears at nominal ac line voltage.

7–31. Reassemble the instrument case and mark the line voltage on the adhesive label (P/N 32-10042-1) provided for that purpose. Apply the label over the unused line voltage markings. On rear panels which list a choice of voltages, check-mark the wired voltage and eliminate the previous marking with tape or a dab of paint.

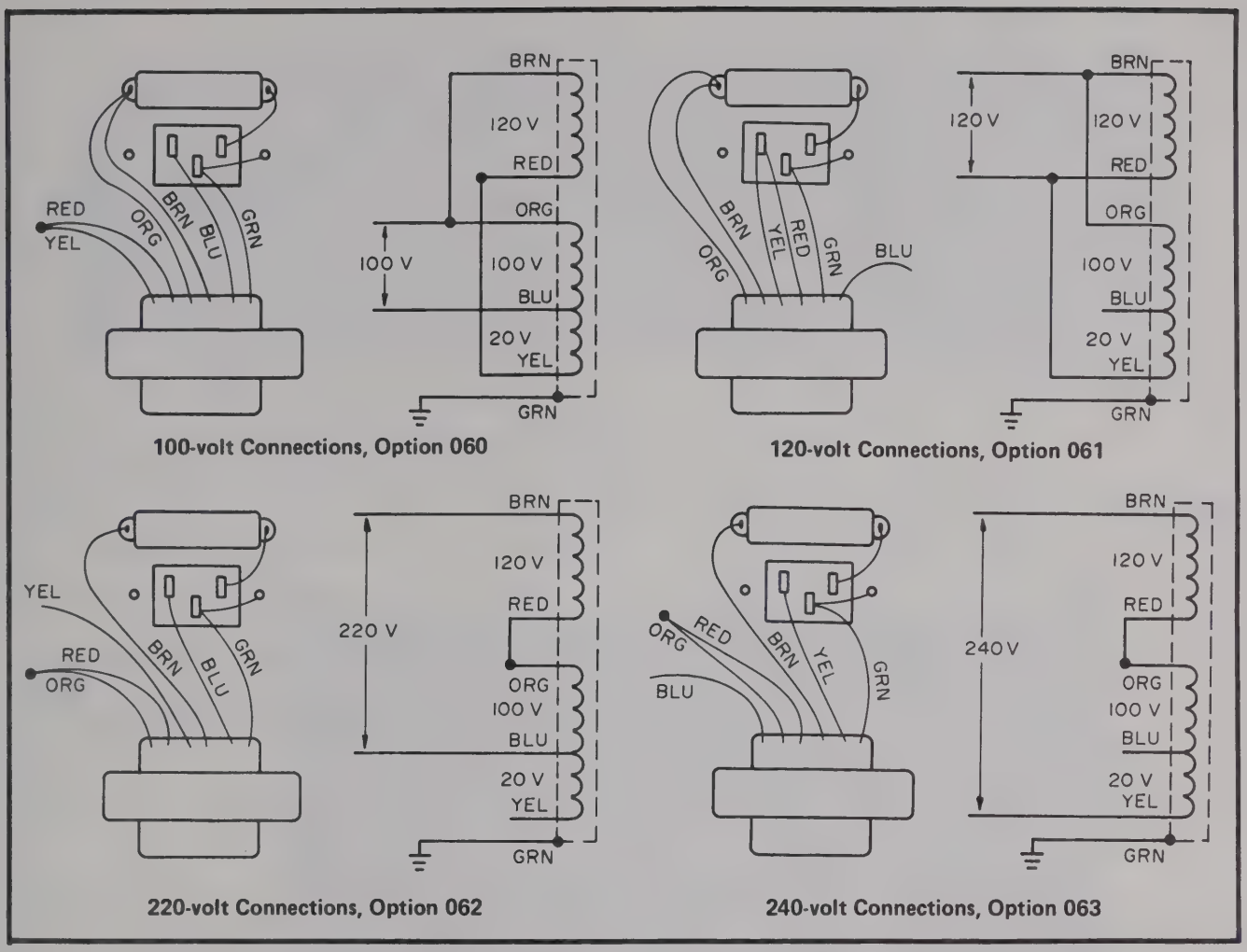


Figure 7–3. Power Transformer Primary Connections

7–32. DIGITAL DISPLAY WITH ANALOG METER, OPTION 20.

7–33. General. Option 20 provides the 3028B with an analog meter in addition to the digital display. (See Figures 7–4 and 7–5.) The meter operates on all ranges and functions. It provides a 0 to 2 linear scale and a –20 dB scale which tracks the digital indication. Zero dB measurements are in dBV referenced to a digital indication of 1000 and dBm measurements refer to 1 milliwatt into 1000 ohms. The meter is used for alignment and null applications and indicates the absolute value of input to the multimeter on all voltage, resistance, and current ranges except the 20 mV, 20 ohm, and 20 μA ranges.

7–34. Specifications.

Electrical: Same as basic 3028B

Meter Accuracy: ±15% full scale from 15°C to 35°C

Temperature Coefficient: –10°C to 15°C and 35°C to 55°C ±(0.25% full scale/°C)

Meter Scale: Length, 20 mm (0.75 inch)
Voltage scale, linear 0 to 2
dB scale, logarithmic, 26 dB range, marked –20 to +6, 0 dB referenced to 1 mW into 1000 ohms.

Meter Type: Edge mount, 2 mA moving magnet, shielded movement

7–35. Operation. No special instructions are required for the operation of the analog meter; the basic operating instructions for the 3028B are applicable.

The dB scale of the meter is calibrated in dB. For dBm measurements, zero dBm is equivalent to 1 milliwatt dissipated by a 1000-ohm load. A reading in dB may be converted to dBm by using the impedance correction graph of Figure 7–6. For example, to convert a +6 reading across 50 ohms to dBm, locate the 50-ohm load-impedance line

on the bottom of the graph. Follow this line to the heavy black line and read the meter correction in dBm at the intersection point. The correction is +13 dBm and the corrected reading is +19 dBm. This example refers to voltage readings on the 2-volt range. The 3028B uses decade attenuators so the 20-dB steps are applicable as follows:

1200 V	Add +60 dB
200 V	Add +40 dB
20 V	Add +20 dB
2 V	Add +0 dB
200 mV	Subtract 20 dB
20 mV	Subtract 40 dB

To obtain the actual dB measurement, add or subtract the dB-attenuator step to the dB reading on the meter.

7–36. Circuit Description. U1 is a gain-of-one impedance converter which is connected to the basic 100 mV range integrator of the A to D converter. The output of U1 drives the drain of FET Q1. The gate of Q1 is driven by the collector output of Q2. This PNP is emitter-driven from the measure-zero signal of the A/D converter. The zero interval is near circuit ground and the measure interval voltage is at approximately 4 volts. Q1 therfore conducts only during the measure interval and acts as a synchronous detector. Q2 is an absolute-value detector operational amplifier. The meter is included in the negative feedback loop and is tied through a diode bridge so that positive or negative inputs to Q2 provide a positive signal. R3 adjusts the meter zero through control of the input offset and R7 acts as a full-scale meter calibration adjustment.

7–37. Calibration.

a. With power off, check that the meter pointer lies over the zero mark on the upper (0-1-2) scale. If not, carefully move the meter's mechanical zero-adjust lever located at the top rear of the meter case, until the pointer is on the zero mark. The DMM should be at 45 degrees or in its normal operating position when making this mechanical adjustment.

b. Push the DMM pushbutton switches S1 to ON, S2 to DC, S3 to V, and S8 to 2.

c. Connect a dc voltage source to the V-Ω and COMMON connectors. Apply approximately +1 volt.

d. Note the reading of the analog meter. Reverse input polarity and adjust R3, the meter zero adjust, to give the same reading. Repeat adjustment of R3 with both input polarities until no difference can be observed in the meter reading when changing the polarity of the input signal.

e. Apply 1.000 V and adjust R7, the meter calibration adjust, for a 1 V indication on the analog meter.

f. Increase input voltage to +1.95 V. The analog meter should deflect within the range of 1.9 to 2.1. If out of these limits, select R8 for full-scale accuracy calibration while continuously rechecking the 1 volt meter calibration of Step e. above.

7–38. Schematic. A schematic diagram of the meter drive circuit is shown in Figure 7–7.

TABLE 7–4. PARTS LIST, ANALOG METER, OPTION 20

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
C 1	07101980A	CCD 100 NF 25 NPO	56289	SPRAG CO69A250M1042
C 3	07101980A	CCD 100 NF 25 NPO	56289	SPRAG CO69A250M1042
C 4	07103390A	CBM 100.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A100K
C 6	07095760A	CCD 10 NF 150 V T 40%	71590	CTL TYP DDM 103
C 7	07103500A	CMD 470.0PF 500.0 V TCE 2%	84171	ARCO DM15ED470G03 ARCO
CR 1	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
CR 2	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
CR 3	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
CR 4	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
CR 5	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
CR 6	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
M 1	18100341K	MTR 3028A/B-20 500UA SPC SCALE	50423	
Q 1	10100580A	TRQ 40673	86684	RCA
Q 2	10094730A	TRQ 2N3906 PNP 1 40 PT0-92	04713	MOT 1 200M 60
R 1	12125000A	RFF 100.0 K 250.0MW FT- 1%	16299	CGW RN55D 1003 F
R 2	12125000A	RFF 100.0 K 250.0MW FT- 1%	16299	CGW RN55D 1003 F
R 3	09100030A	RVC 100.0 K 0.5 WK +-10%	73138	HEL TYP 72PM
R 4	12125000A	RFF 100.0 K 250.0MW FT- 1%	16299	CGW RN55D 1003 F
R 5	12125680A	RFF 511.0 K 500 MW F+-1%	16299	CGW RN60D 5113F
R 6	12126000A	RFF 1.00M 500 MW F+-1%	16299	CGW RN60D 1004F
R 7	09100060A	RVC 1.0 K 0.5 WK +-10%	73138	HEL TYP 72PM
R 8	12122880A	RFF 825.0 250.0MW FT- 1%	16299	CGW RN55D 8250 F
R 9	12122000A	RFF 100.0 250.0MW FT- 1%	16299	CGW RN55D 1000 F
U 1	24102750A	1CP TL061 OP AMP	01295	TI
U 2	24102750A	1CP TL061 OP AMP	01295	TI

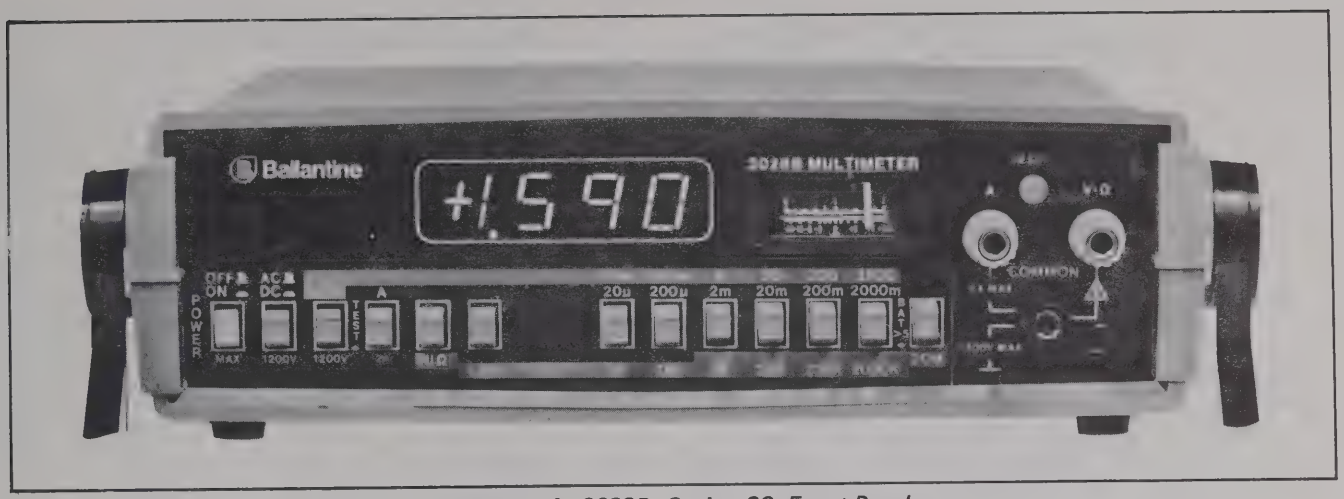


Figure 7–4. 3028B, Option 20, Front Panel

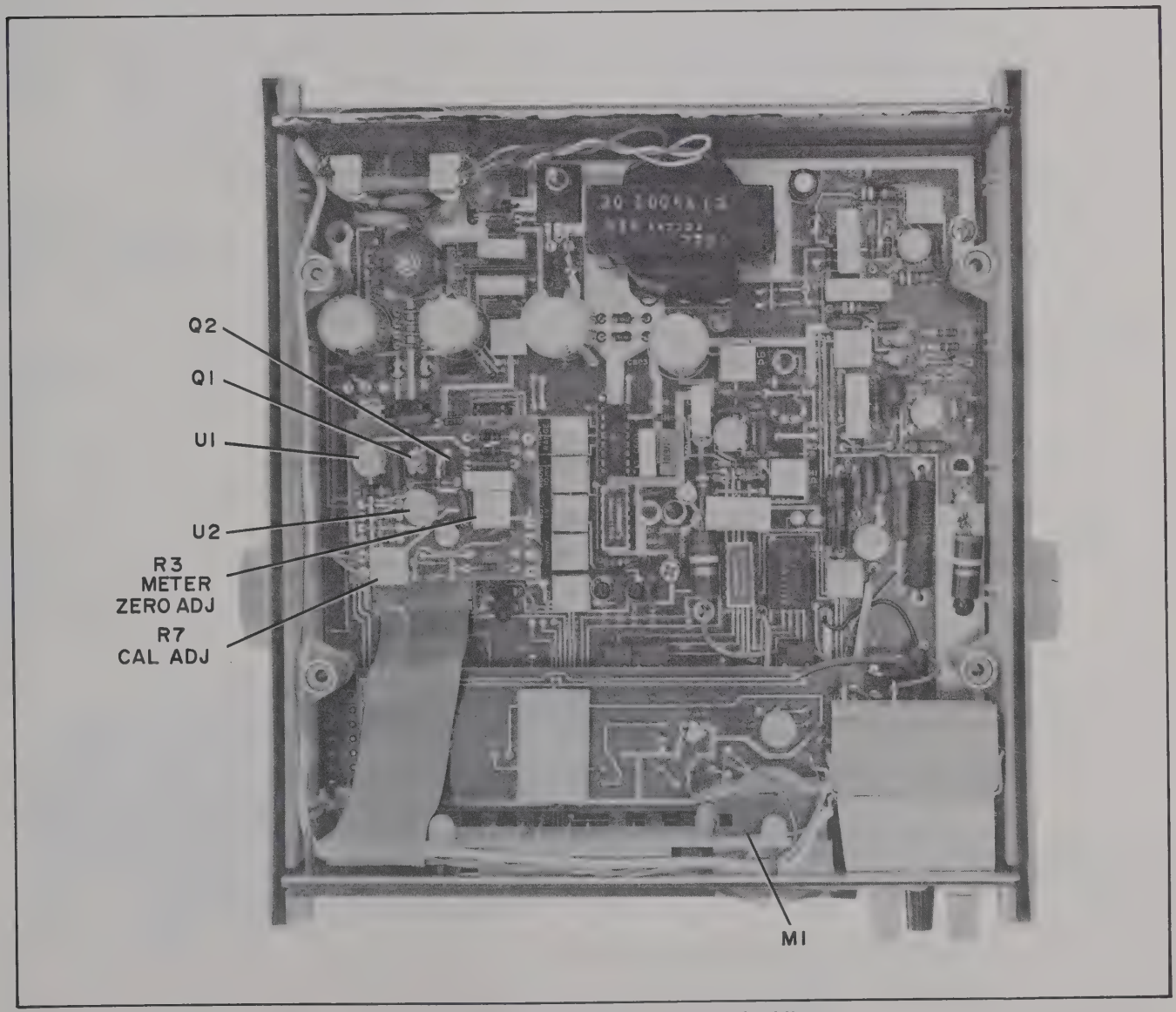


Figure 7–5. 3028B, Option 20, Interior View

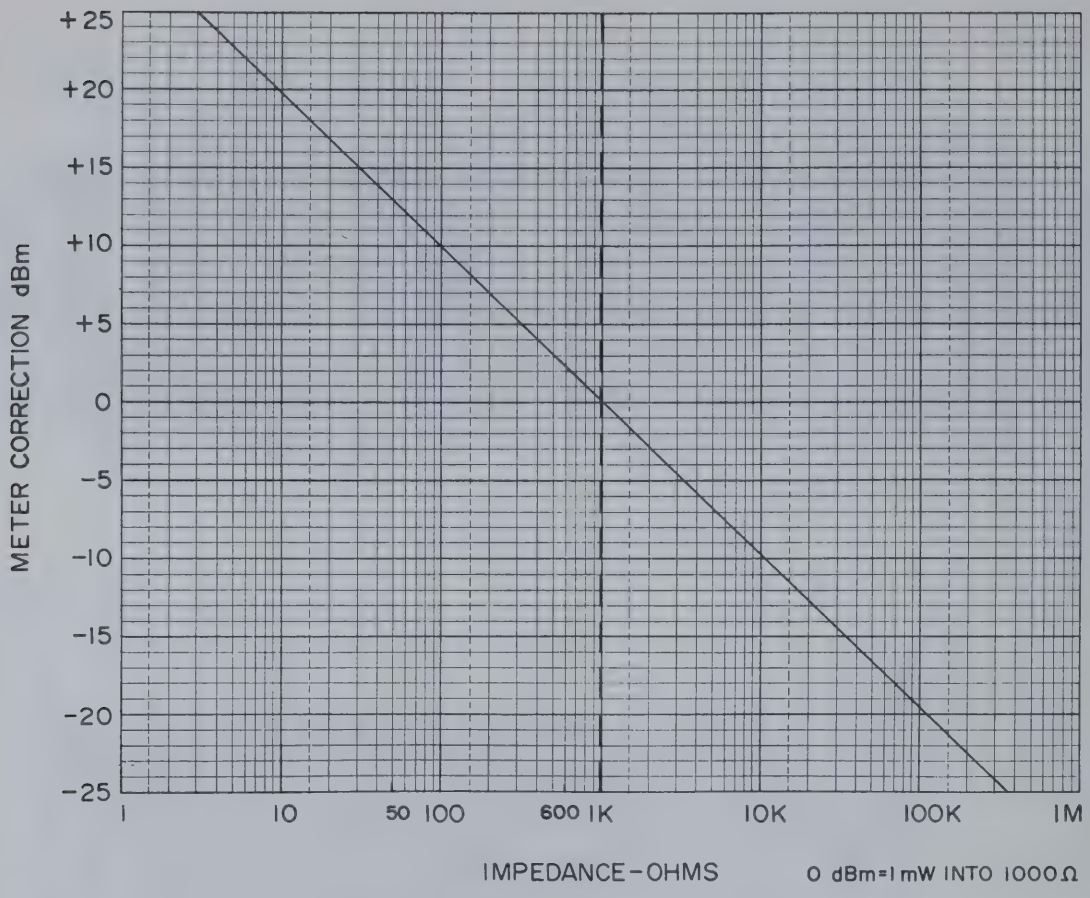


Figure 7–6. Impedance Correction Graph

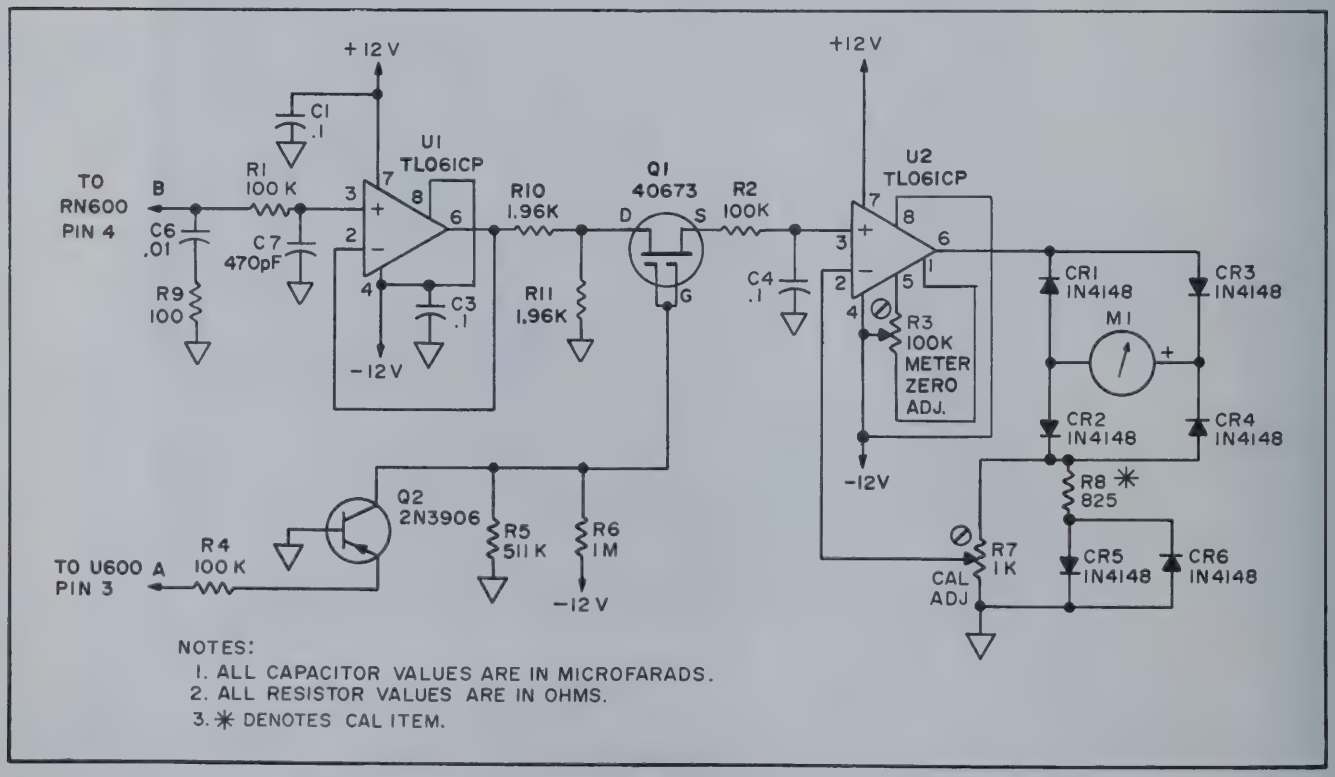


Figure 7–7. Option 20, Analog Meter Drive Circuit, Schematic Diagram

7–39. 20-AMPERE CURRENT RANGE, OPTION 21.

7–40. General. The 20-ampere current range option extends the current measuring capability of the 3028B to 20 amperes for both ac and dc rms current. Continuous measurements may be made to 10 amperes. Currents to 15 amperes are limited to 1½ minutes and a duty cycle of 50%. Currents to 20 amperes are limited to 1 minute and a duty cycle of 25%. The standard performance characteristics and specifications of the 3028B are not altered with Option 21 installed.

7–41. DC Specifications.

Ranges: ±20.00 amperes
1.5-minute operation to ±15 amperes
1-minute operation to ±20 amperes

Accuracy (15° to 35°C): ±(0.5% of reading + 1 LSD)

Voltage Burden: 0.5 V maximum to 10 A

Maximum Input: ±20 amperes

Operating Time: Continuous to ±10 amperes
1.5 minutes to ±15 amperes (50% duty cycle)
1 minute to ±20 amperes (25% duty cycle)

Response Time: 500 ms

7–42. AC Specifications.

Ranges: 20 amperes
1.5-minute operation to 15 amperes
1-minute operation to 20 amperes

Accuracy (+15°C to +35°C):
15 Hz to 10 kHz (sine wave) ±(2% of reading + 3 LSD)
45 Hz to 3 Khz (sine wave) ±(1% of reading + 2 LSD)
For distorted waveforms having less than 10% total harmonic distortion with no single harmonic greater than 5%, add ±(1.5% + 2 LSD) to the sine wave accuracy specified.

Voltage Burden: 0.5 V to 10 A for sine waves

Maximum Input: 20 A

Operating Time: Continuous to 10 A
1.5 minutes to 15 A (50% duty cycle)
1 minute to 20 A (25% duty cycle)

Response Time: 3 seconds maximum

7–43. Operation.

a. Push the DMM pushbutton switches S1 to ON, S2 to AC or DC as required, S4 to A, and S9 to 20m.

b. Connect the input current leads to tight-fitting, clean, banana plugs which are connected to the 20-ampere range banana jacks on the front panel. Observe polarity for dc current measurements by connecting negative lead to LO connector. Always use the LO connector for the LO side of ac current inputs.

CAUTION

Do not exceed 20 amperes and the duty factors specified. Always set all switches before connecting signal to the 20-ampere input.

7–44. Theory of Operation. A schematic diagram of the 20-ampere current range option is shown in Figure 7–8. A 0.01-ohm resistor is inserted into the low-end sensing return of the 0.1-ohm shunt resistor of R201. The 0.01 ohm resistor is also a four-terminal network and is connected directly to its own input connector to avoid additional range switching. Proper positioning of the decimal point is performed by depressing the 20m range pushbutton S9.

7–45. Replaceable Parts.

R1200	Resistor, 0.01 ohm, four-terminal	P/N 12129551
—	Window	P/N 47100341

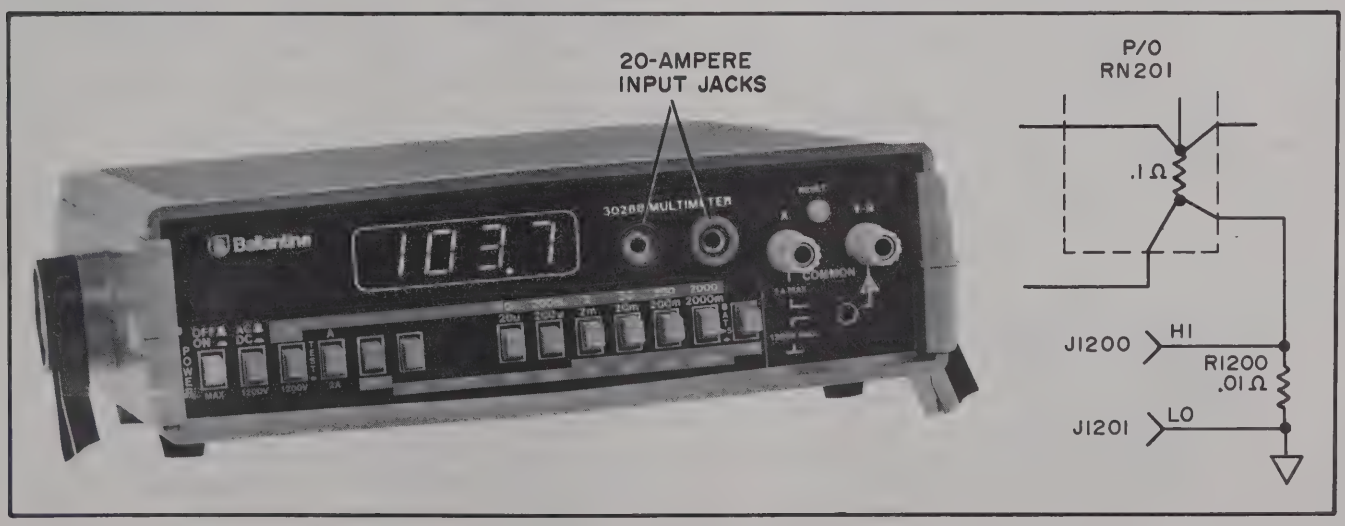


Figure 7–8. Option 21, Front Panel and Schematic Diagram

7–46. AC AVERAGE RESPONDING DIGITAL MULTIMETER, OPTION 24.

7–47. General. Option 24 is an average responding ac converter version of the standard Ballantine 3028B. AC voltage and current range specifications are changed and the highest-sensitivity voltage resistance and current ranges are deleted.

7–48. Specifications. DC voltage, resistance, and dc current specifications listed in paragraph 1–9 are unchanged except that the 20 mV, 20 ohm, and 20 μA ranges are deleted.

AC VOLTAGE.

Range	Maximum Scale	Resolution
200 mV	199.9 mV	100 μV
2 V	1.999 V	1 mV
20 V	19.99 V	10 mV
200 V	199.9 V	100 mV
1200 V	1200 V	1 V

Accuracy (sine wave): 1 year, 15°C to 35°C
Frequency response (referenced to 400 Hz)
Usable <20 Hz to >50 kHz
40 Hz to 10 kHz:
Sine wave, ±(0.5% of reading +2 LSD)
10 kHz to 20 kHz:
Sine wave, ±(1% of reading +2 LSD)

Response: Average responding. Calibrated in rms of a sine wave.

Temperature Coefficient:
–10°C to 15°C and 35°C to 55°C
±(0.01% of reading/°C +0.005% of Full Scale/°C)

Input Impedance: 10 MΩ in parallel with less than 100 pF on all ranges.

Common Mode Rejection (1 kΩ unbalance and COMMON driven): Greater than 120 dB at dc and 60 dB at 50 Hz or 60 Hz.

DC Blocking Voltage (Normal Mode): ±1200 volts dc maximum.

Maximum Input Voltage: 1200 v rms sinusoidal on all ranges. Not to exceed 10^8 Volt-Hz.

Response Time: 3 seconds; typically 1 second within one range.

AC CURRENT.

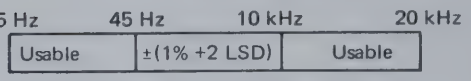
Range	Max. Scale	Resolution	Input Resistance
200 μA	199.9 μA	100 nA	1000 Ω
2 mA	1.999 mA	1 μA	100 Ω
20 mA	19.99 mA	10 μA	10.1 Ω
200 mA	199.9 mA	100 μA	1.15 Ω
1200 mA	1999 mA	1 mA	0.25 Ω

Response: Average responding. Calibrated in rms of a sine wave.

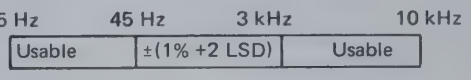
Accuracy (sine wave): 1 year, 15°C to 35°C

Percent of Reading – 400 Hz Reference.

All Ranges Except 2000 mA



2000 mA Range



Temperature Coefficient:
–10°C to 15°C and 35°C to 55°C
±(0.015% of reading/°C + 0.005% of Full Scale/°C)

Maximum Input: 2 amperes (dc plus ac rms). Protected by resettable circuit breaker and diode clamps to 15 A peak.

Voltage Burden at Full Scale: 0.25 volt maximum on all ranges except 0.5 volts FS on the 2000 mA range.

Response Time: 3 seconds (within one range)

7–49. Operation. The 3028B Option 24 multimeter responds to the average of the ac input signal and is calibrated in rms of an undistorted sine wave input. If the input voltage is not sinusoidal, the resulting measurement error may be considerable. The amount of error depends upon the number and percentage of harmonics present as well as their phase relationships. RMS calibration is used since rms gives the true measure of the power capability or heating value of the input waveform.

7–50. Ballantine offers other instruments such as the Model 3620A and the standard 3028B which respond to the true rms of the input waveform. A true rms instrument should always be used to measure ac voltages which have considerable harmonic content or nonsinusoidal voltages such as may be found in ac/dc rectifiers, SCR devices, pulse trains, square waves, inductive loads, power measurements, and noise measurements.

An unknown voltage which is not sinusoidal may be displayed and analyzed on an oscilloscope. However, a meter cannot give an indication of this kind, and the user cannot know from a digital or analog voltmeter presentation what distortion might be present in the signal under test.

7–51. AC signals are often highly distorted and the operator must consider that ac measurement accuracies are specified for sinusoidal signals. Errors may be identified through Table 7–5. The 3028B, Option 24 is average responding and calibrated in rms of a sine wave.

7–52. All other ac measurement conditions listed in Section 3 are applicable to the 3028B, Option 24.

7–53. Theory of Operation. All of the discussion of Section 4 is applicable to the 3028B, Option 24, except for paragraph 4–22. See Figure 6-2.

7–54. AC to DC Converter (Reference Designator 400 Series). The ac-to-dc converter takes the ac input signal from the input voltage divider or the current shunts and converts it into a dc voltage. This dc voltage is then measured by the dc voltage analog-to-digital converter. The ac-to-dc converter is a wideband circuit operating from <25 Hz to beyond 50 kHz and over a dynamic range of 100 μV to beyond 2 volts rms. See Figure 7–9 for a simplified diagram of the ac converter.

7–55. The input to the ac converter consists of field effect transistor Q400. This dual gate MOSFET is connected with PNP Q401 to provide high-input impedance and low-output impedance. It has internal diode protection for input overloads. Resistor R400 is the voltage-dropping resistor which limits the FET input current to avoid damage during overloads.

7–56. The input FET follower (Q400) and transistor (Q401) drive the noninverting input of operational amplifier U400. Diode CR401 protects the input of U400 from overloads. Feedback from the output of U400 to its inverting input causes the operational amplifier output to follow the input signal from FET follower Q400. This results in a current flow from ground through R408 plus R409 which is equal to $E_{in}/(R408 + R409)$. Diodes CR402 and CR403 conduct on alternate cycles of the input ac waveform. Therefore, one-half the average current flows through R406. The ac-to-dc converter is an operational full-wave rectifier and the voltage at the junction of CR403 and R406 is sent through low-pass filter R411 and C410 for measurement by the dc analog voltage-to-digital converter. The detector responds to the average of the ac signal input and is calibrated in rms of a sine wave.

7–57. The input to the ac converter is either 200 mV or 2 V full scale. The circuit is designed to operate over this two-decade dynamic range without changing gain. AC conversion gain is adjusted by R409.

7–58. Replaceable Parts. All parts lists in Section 6 are applicable, except delete all 500 Series reference designator parts and

R408 12122920A RFF 909 Ω 500 mW ±1% – RN55

Add:

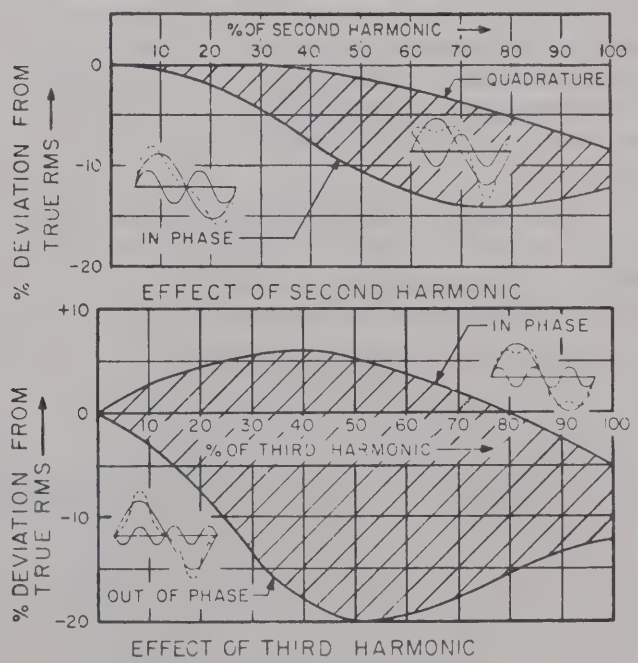
R408 12122880A RFF 825 Ω 500 mV ±1% – RN55

7–59. Delete all measurements and references above 20 kHz from Table 5–4 (AC Voltage Accuracy Check), Table 5–5 (Optional AC Current Accuracy Check), and Form 5–1 (Performance Test Record).

TABLE 7–5. EFFECTS OF DISTORTION ON ACCURACY

HARMONIC	% DISTORTION	% ERROR (* Fundamental)	
		MAX. POSITIVE	MAX. NEGATIVE
Any even	0.1	0.000	
	0.5	0.001	
	1.0	0.005	
	2.0	0.020	
Third	0.1	0.033	0.033
	0.5	0.168	0.167
	1.0	0.338	0.328
	2.0	0.687	0.667
Fifth	0.1	0.020	0.020
	0.5	0.101	0.099
	1.0	0.205	0.195
	2.0	0.420	0.380

*Depends on phase relationship between harmonic and fundamental.



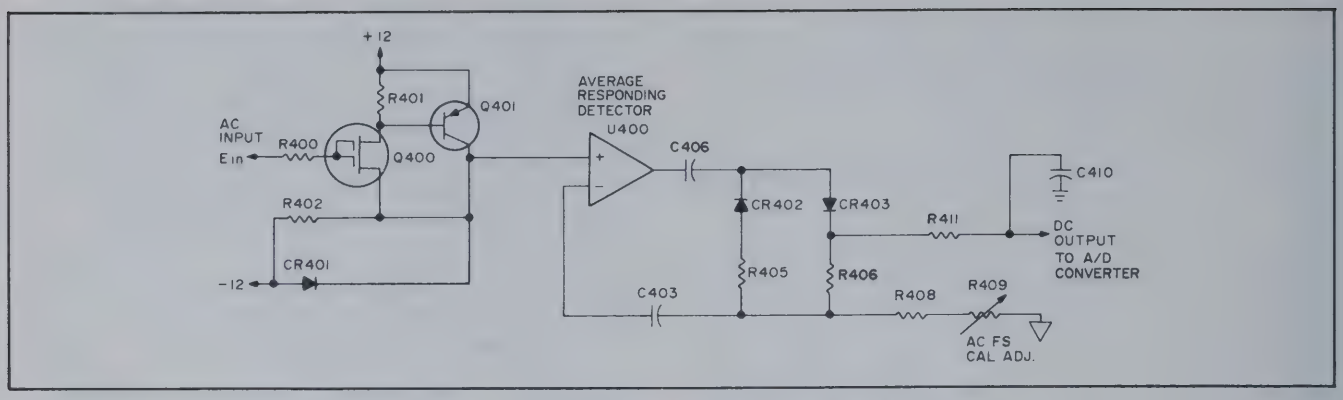


Figure 7–9. AC Converter, Simplified Diagram

7–60. TRANSIENT OVERVOLTAGE PROTECTION, OPTION 25.

7–61. General. Option 25 equips the 3028B with additional ac power line filtering and line transient surge protection to ensure optimum accuracy and maintenance-free use when the instrument is operated from ac power lines which have high-transient voltage surges. This option is recommended when the 3028B is operated in high-altitude areas or in industrial environments when pumps, elevators, X-ray machines, spark gaps, magnetic activators, and other high-power equipment may cause voltage surges on the power line. In addition, Option 25 provides extra signal input overvoltage protection by the addition of two catch diodes in the input of the dc to digital converter. Transient input signal overvoltage protection to 6 kV is provided by the metal oxide varistor limiting devices RV900 through RV907.

7–62. Specifications. Except for the input shunt capacity, which is increased to 130 pF maximum, none of the specifications and operating characteristics of the basic 3028B are changed with the addition of Option 25.

7–63. Installation. Transient overvoltage protection Option 25 is easily installed in the field. Remove the covers of the instrument (refer to paragraph 5–33). Remove the main printed wiring assembly and solder in diodes CR601 and CR602. CR601 and CR602 are installed into the spaced marked on the main printed wiring board. Observe polarity. Add the two capacitors C902 and C903 from the HI and LO side of the ac power input receptacle J50 to its earth ground pin. Make the capacitor leads as short as possible. Add the metal oxide varistor (MOV) surge suppressor RV900 across one primary of power transformer T900. This is readily done in the 120-volt connection by soldering RV900 from the LO pin of power receptacle J50 to the LO side of the fuse post holding F50. When Option 06 is installed and the 100-volt or 120-volt mode is selected, also solder RV900 to the pins of J50 and F50.

For 220-volt and 240-volt operation, also solder RV901 from LO of J50 to the floating junction of the primaries making certain that the joint is well-insulated. After installing all parts, reassemble the printed circuit board and panels to the bottom cover. Perform the tests of the Performance Assurance Tests of paragraph 5–7 and give special attention to the adjustment of R605, the input offset adjustment control. Replace the cover and attaching hardware.

7–64. To install the input connector surge suppressors, first disconnect the wire from the V–Ω connector to the high-voltage printed wiring board and remove the solder jumper connection between the two connector holes where the wire was removed. Then connect the four varistors in series and join the two other varistors to the string of four. See Figure 6-4. Sleeve the varistors and solder the last of the string of three directly to the COMMON binding post. Tie each of the other two varistors to the open connection holes on the high voltage board. Keep wires and varistors short and dressed away from other components. Then add R905 (2.2 k) from the V–Ω connector to the closest hole which is tied to S2. Solder to the varsitor lead. Then add inductor L900 from the V–Ω connector to the hole and varsitor tied to S3. Solder this lead.

7–65. Diagrams. See Figure 7–10 for the circuit diagram. Figure 6-4 shows the locations of CR601, CR602, R903, R904, R905, L900, and RV902 to RV907.

TABLE 7-6. PARTS LIST, TRANSIENT OVERVOLTAGE PROTECTION, OPTION 25

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
C.902	07-02543-0A	CCD 1.5NF 3 KV M -20+80%	72982	ERIE 878 H1-K DISC Y5V
C.903	07-02543-0A	CCD 1.5NF 3 KV M -20+80%	72982	ERIE 878 H1-K DISC Y5V
CR601	05-10103-0A	DXS PAD50 35.0V .50M	17856	SIL PAD50 PICOAMP 51
CR602	05-10103-0A	DXS PAD50 35.0V .50M	17856	SIL PAD50 PICOAMP 51
L.900	03-10057-0A	CRF 470 MH 10 OHM ENCAP-AXIA	83125	NYTRONICS WEE 470
L.901	03-10057-0A	CRF 470 MH 10 OHM ENCAP-AXIA	83125	NYTRONICS WEE 470
R.903	12-12935-0A	RFC 47.0 M 1.0 W K+-10%	1121	A-B GB
R.904	12-01004-0A	RFC 3.9 M 500.0MW J+- 5%	1121	A-B TYP EB
RV900	14-10000-0A	REG LINE SURGE SUPPRESSOR	24446	GE VP 150A10
RV901	14-10017-0A	REG SURGE SUPPRESSOR 253 VRM	24446	GE V430MA3A AXIAL LEADS
RV902	14-10017-0A	REG SURGE SUPPRESSOR 253 VRM	24446	GE V430MA3A AXIAL LEADS
RV903	14-10017-0A	REG SURGE SUPPRESSOR 253 VRM	24446	GE V430MA3A AXIAL LEADS
RV904	14-10017-0A	REG SURGE SUPPRESSOR 253 VRM	24446	GE V430MA3A AXIAL LEADS
RV905	14-10017-0A	REG SURGE SUPPRESSOR 253 VRM	24446	GE V430MA3A AXIAL LEADS
RV906	14-10017-0A	REG SURGE SUPPRESSOR 253 VRM	24446	GE V430MA3A AXIAL LEADS
RV907	14-10017-0A	REG SURGE SUPPRESSOR 253 VRM	24446	GE V430MA3A AXIAL LEADS

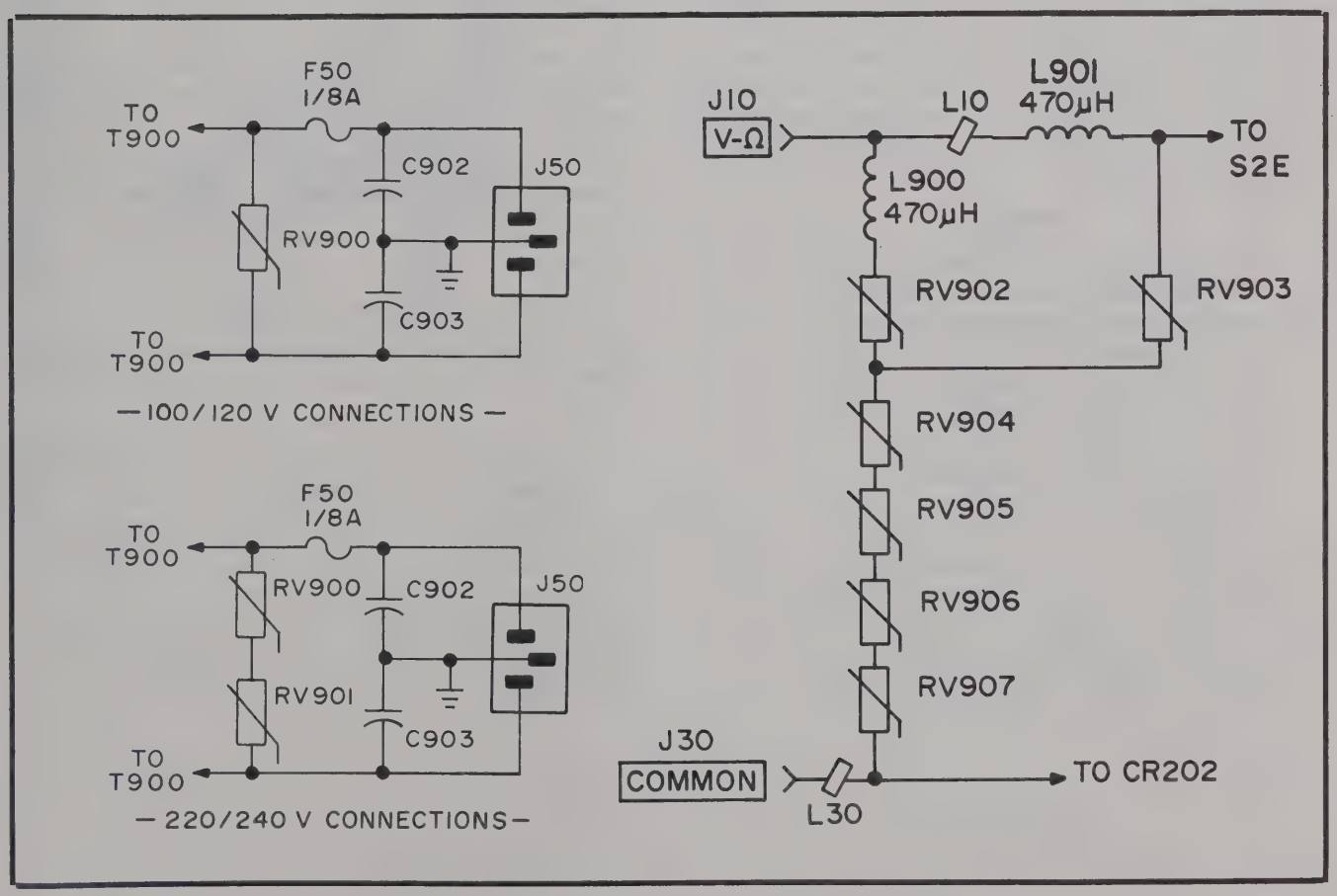


Figure 7–10. Option 25, Transient Overvoltage Protection Power Input, Schematic Diagram

7–66. DC HIGH VOLTAGE PROBE MODEL 10800B.

7–67. General. The Ballantine Model 10800B DC High Voltage Probe, shown in Figure 7–11, is used to provide the instrument with a dc voltage capability to ±40,000 volts. The probe has a division ratio of 1000:1 and features a ±5% adjustment range for precise calibration at any voltage input.

7–68. Specifications.

Voltage Range: ±1 kV to ±40 kV

Input Resistance: 1000 megohms

Division Ratio: 1000:1

Accuracy: ±1% referenced to calibration point
Voltage Coefficient:
2 ppm per volt, 1 to 10 kV (2%)
3 ppm per volt, 10 to 20 kV (3%)
5 ppm per volt, 20 to 40 kV (4%)

Maximum Input: ±40 kV peak

7–69. Operating Precautions. Before using the 10800B probe, connect a 3.3 MΩ, 1/2 W resistor (P/N 12129340A) from the neutral terminal of J50, the ac power receptacle, to earth ground, and a 47 MΩ, 1 W resistor (P/N 12129350A) from the instrument COMMON to earth ground. These resistors will minimize shock hazard and equipment damage should the probe ground lead be disconnected accidentally. Also, with this modification, the dc common mode rejection will decrease to 90 dB.

WARNING

BEFORE CONNECTING THE HV PROBE, CONNECT THE GROUND-LEAD CLIP OF THE PROBE SECURELY TO THE GROUND (LO) OF THE CIRCUIT UNDER TEST. FAILURE TO OBSERVE THIS PRECAUTION WILL APPLY FULL HIGH VOLTAGE TO THE INSTRUMENT WHICH MAY CAUSE PERSONNEL SHOCK AND INSTRUMENT DAMAGE. THE GROUND-LEAD VOLTAGE MUST NOT EXCEED ±1200 VOLTS PEAK TO THE POWERLINE EARTH GROUND. HANDLE THE PROBE ONLY AT ITS BLACK HANDLE AND AVOID CONTACT WITH THE FLASH GUARD AND TIP AREA.

7–70. Operating Procedure.

a. Push the DMM pushbutton switches S1 to ON, S2 to DC, and S3 to V.

b. Select the DMM 2 range for operation to ±2 kV, the 20 range for operation to ±20 kV, or the 200 range for operation up to ±40 kV. The display will read directly in kV.

c. Plug the termination of the 10800B probe into the V–Ω and COMMON connectors of the instrument, making sure that the red-marked banana plug of the termination mates with the V–Ω connector of the instrument.

d. Connect the ground-lead clip of the probe to the ground (LO) of the circuit under test.

e. Connect the probe tip to the circuit under test.

f. Turn the equipment on to apply the signal and read the instrument display.

7–71. Calibration.

a. Push the DMM pushbutton switches S1 to ON, S2 to DC, S3 to V, and S8 to 2.

b. Plug the 10800B probe termination into the V–Ω and COMMON connectors of the instrument, making sure that the red-marked banana plug of the termination mates with the V–Ω connector of the instrument.

c. Remove the four screws from the cover of the probe termination box and remove the cover to gain access to the potentiometer, R2.

d. Connect the ground-lead clip of the probe to the ground of a Fluke Model 332B DC Voltage Standard.

e. Connect the probe tip to the HI output of the Model 332B.

f. Apply ±1000.00 volts.

g. Use an insulated screwdriver and adjust R2 for a DMM display of .999 to 1001.

Note

Calibration may be performed at any voltage to 40 kV using other voltage standards and DMM ranges.

h. Replace the cover of the probe termination box and secure it with the four screws.

7–72. Schematic Diagram. A schematic diagram of the Model 10800B DC High Voltage Probe is shown in Figure 7–12.

TABLE 7–7. PARTS LIST, DC HIGH VOLTAGE PROBE MODEL 10800B

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
R 1	09101640A	RVF 500.0 K 250 MW K CERMET	73138	HELIPOT 72XW VERT MT
R 2	1212592OA	RFF 909.0 K 500 MW F+-1%	16299	CGW RN60D9093F
---	79071410A	CBL 20-1 CONDUCTOR PLASTIC	92194	ALPHA NO. 1706
---	79045230A	WIRE, TEST LEAD, BLK	50423	
---	49044360A	ALLIGATOR CLIP	76545	MUELLER NO. 60

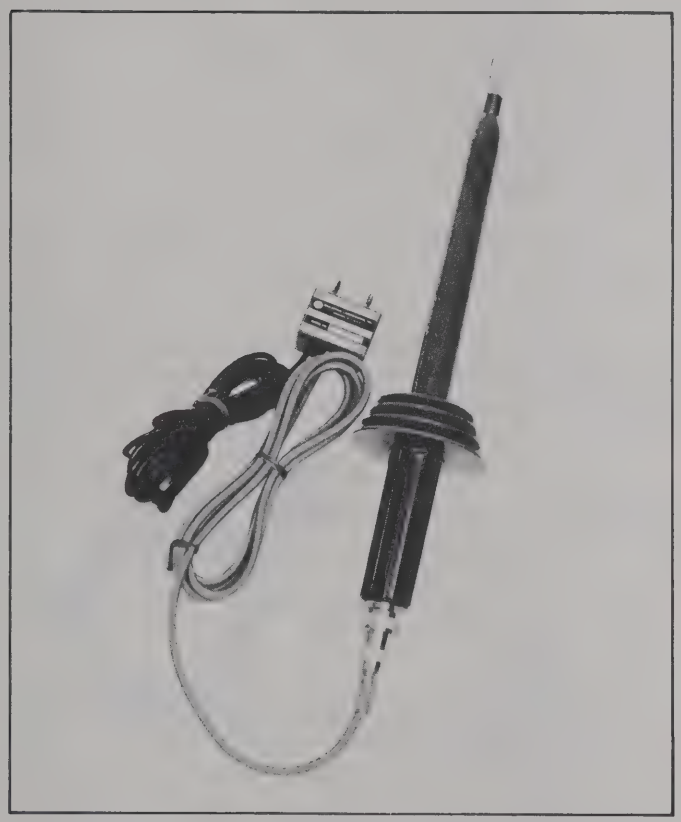


Figure 7–11. Model 10800B DC High Voltage Probe

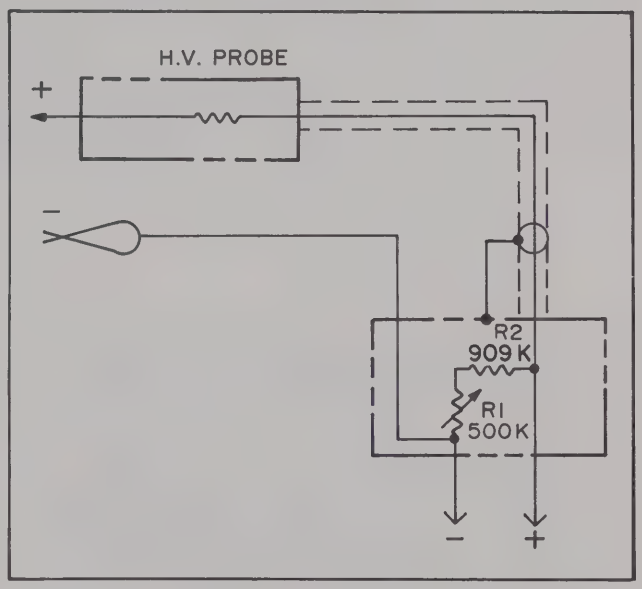


Figure 7–12. Model 10800B DC High Voltage Probe, Schematic Diagram

7–73. AC HIGH VOLTAGE PROBE MODEL 1301B.

7–74. General. The Ballantine Model 1301B AC High Voltage Probe, shown in Figure 7–13, is used to extend the ac rms voltage range of the instrument to 10 kV rms (14 kV peak). The probe has a capacitive division ratio of 10,000:1 (80 dB) and features a ±5% adjustment range for precise calibration at any voltage amplitude and frequency input. The 1301B is not a detector probe and therefore retains the rms response of the 3028B. Although the probe is usable beyond 6 MHz, its usefulness with the 3028B is limited to the specifications of the 3028B.

7–75. Specifications (with 3028B).

Voltage Range: <1 kV to 10 kV rms (14 kV peak)

Input Impedance: <10 pF in parallel with 1000 megohms

Division Ratio: 10,000:1 (80 dB)

Maximum Input: 10 kV rms sinusoidal; 14 kV peak

Accuracy: Adjustable ±1% to any reference condition within the specification
All accuracies are additive to the accuracies of the 3028B
45 Hz to 10 kHz ±1%
40 Hz to 110 kHz ±2%

7–76. Operating Precautions. Before using the 1301B probe, connect a 3.3 MΩ, 1/2 W resistor (P/N 12129340A) from the neutral terminal of J50, the ac power receptacle, to earth ground, and a 47 MΩ, 1 W resistor (P/N 12129350A) from the instrument COMMON to earth ground. These resistors will minimize shock hazard and equipment damage should the probe ground lead be disconnected accidentally. Also, with this modification, the dc common mode rejection will decrease to 90 dB.

WARNING

BEFORE CONNECTING THE HV PROBE, CONNECT THE GROUND-LEAD CLIP OF THE PROBE SECURELY TO THE GROUND (LO) OF THE CIRCUIT UNDER TEST. FAILURE TO OBSERVE THIS PRECAUTION WILL APPLY FULL HIGH VOLTAGE TO THE INSTRUMENT WHICH MAY DAMAGE THE EQUIPMENT AND PRESENT A SHOCK HAZARD. GROUND LEAD SHOULD BE CONNECTED TO POWER LINE EARTH GROUND. GRASP THE PROBE ONLY AT ITS HANDLE AND AVOID CONTACT WITH THE FLASH GUARD AND TIP AREA. CONNECT PROBE WITH POWER OFF AND AVOID HAND HELD PROBE OPERATION.

WARNING

USE OF AN AC PROBE TO MEASURE RF VOLTAGE IN HIGH POWER AND/OR TUNED CIRCUITS MAY CAUSE HAZARDOUS CONDITIONS DUE TO RESONANCES OR LEAKAGE PATHS. USE EXTREME CAUTION AND UNDERSTAND TEST CONDITIONS OF UNIT UNDER TEST TO AVOID SHOCK HAZARD. USE HIGH VOLTAGE SAFETY GLOVES AND CONNECT PROBE TO UNIT UNDER TEST WITH POWER OFF. AVOID HAND HELD PROBE USE ON HIGH POWER, LOW IMPEDANCE OR ANY CIRCUITS WHICH HAVE VOLTAGES AND CURRENTS THAT MAY PRODUCE SHOCK HAZARD.

7–77. Operating Procedure.

a. Push the DMM pushbutton switches S1 to ON, S2 to AC, and S3 to V.

b. Select the DMM 200 mV range for operation to 2 kV and the 2 range for operation up to 10 kV. The display will read directly in kV.

c. Plug the termination of the 1301B probe into the V–Ω and COMMON connectors of the instrument, making sure that the red-marked banana plug of the termination mates with the V–Ω connector of the instrument.

d. Connect the ground-lead clip of the probe to the ground (LO) of the circuit under test.

e. Connect the probe tip to the circuit under test.

f. Turn the equipment on to apply the signal and read the instrument display.

7–78. Calibration.

a. Push the DMM pushbutton switches S1 to ON, S2 to AC, S3 to V, and S7 to 200 mV.

b. Plug the 1301B probe termination into the V–Ω and COMMON connectors of the instrument, making sure that the red-marked banana plug of the termination mates with the V–Ω connector of the instrument.

c. Unscrew the tip of the 1301B probe to provide access to the calibration adjustment screw.

d. Connect the ground-lead clip of the probe to the ground of an ac voltage calibrator.

e. Connect the probe tip to the ac calibrator and apply 1 kV at 1 kHz.

f. Adjust the probe calibration screw with an insulated screwdriver until the DMM display reads .997 to 1.003.

g. Reinstall the probe tip and recheck the calibration.

7–79. Schematic Diagram. A schematic diagram of the Model 1301B AC High Voltage Probe is shown in Figure 7–14.

TABLE 7–8. PARTS LIST, AC HIGH VOLTAGE PROBE MODEL 1301B

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
C 2	07081060A	CSM 27 NF 100 V J+-5%	92741	GOODALL TYPE 820UB
R 1	12012240A	RFC 2.7 250 MW K+-10%	01121	A-B TYPE CB
R 2	12012240A	RFC 2.7 250 MW K+-10%	01121	A-B TYPE CB
R 3	12012250A	RFC 22.0 M 250 MW K+-10%	01121	A-B TYPE CB
R 4	12012250A	RFC 22.0 M 250 MW K+-10%	01121	A-B TYPE CB
R 5	12012250A	RFC 22.0 M 250 MW K+-10%	01121	A-B TYPE CB
R 7	12011230A	RFC 2.2M 500.0MW J+-5%	1121	A-B TYPE EB
---	89054691A	GROUND LEAD ASSY	50423	
---	80070000A	SILICONE SEALING COMPND	71984	DOW CORNING NO. 5

WARNING

NEVER OPERATE THIS PROBE WITHOUT A SECURE EARTH GROUND CONNECTION, AND USE HIGH VOLTAGE SAFETY GLOVES TO AVOID SHOCK HAZARD.

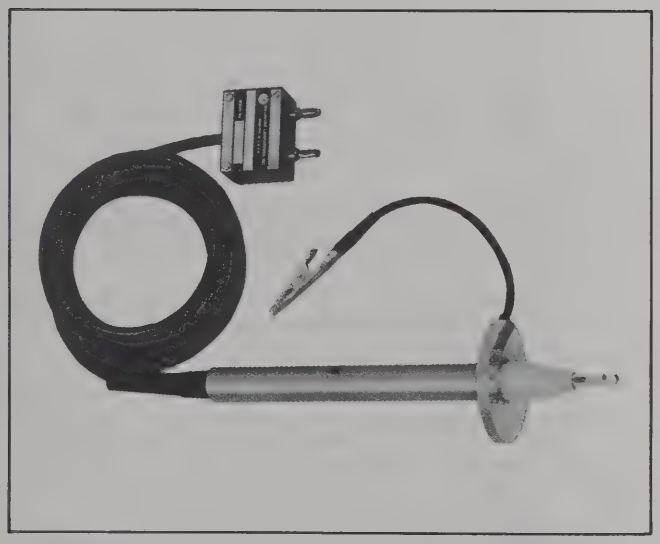


Figure 7–13. Model 1301B AC High Voltage Probe

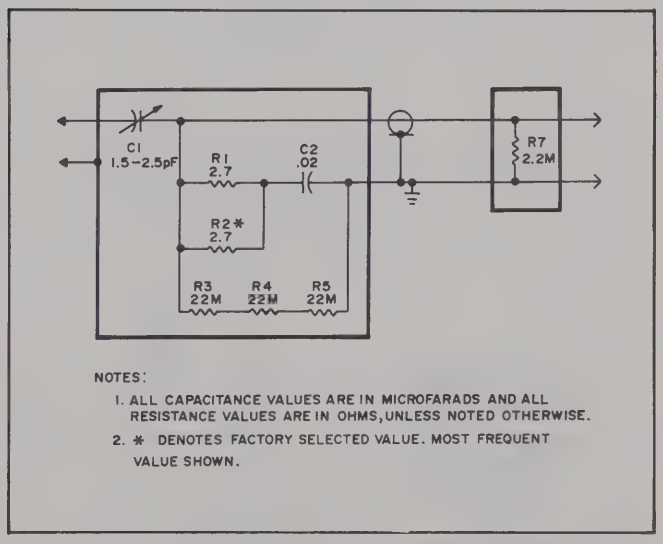


Figure 7–14. Model 1301B AC High Voltage Probe, Schematic Diagram

7–80. RF DETECTOR PROBE MODEL 10850B.

7–81. General. The Ballantine Model 10850B RF Detector Probe, shown in Figure 7–15, is a peak detector probe calibrated in rms voltage. It uses semiconductor diodes and provides measurement capability beyond 700 MHz for sinusoidal signals. The maximum signal is 30 volts rms and a blocking capacitor will hold off dc to a maximum of ± 200 volts.

7–82. Specifications.

Frequency Range: < 50 kHz to > 700 MHz

AC to DC Transfer Accuracy (20°C to 30°C):

May be adjusted to within ±1% at any one frequency from 100 kHz to 100 MHz at a level of 1 volt rms input.

Frequency Response:

100 kHz to 1 MHz ± 1 dB
1 MHz to 100 MHz ± 0.5 dB
100 MHz to 270 MHz ± 1 dB
270 MHz to 470 MHz ± 3 dB

Linearity: 1 dB from 0.75 volts to 5 volts typically within ±3dB over the entire dynamic operating range.

Maximum Input Voltage:

RF 30 volts RMS sinusoidal
DC ±200 volts

Operating Voltage Range:

Usable from 10 mV to 30 Vrms sinusoidal.
Specified range from 250 mV to 30 V rms.

Input Capacity:

≈4.5 pF

Output:

DC Voltage proportional to the input rms of sine wave when terminated by a 10 MΩ load.

Detector Response:

Peak responding and calibrated in rms of a sine wave.

Cable Length:

1.5 meters (5 feet); terminated in dual banana plugs spaced 0.75 inches apart.

Accessories:

Ground lead with alligator clip,
BNC adapter sleeve, retractile hook tip.

7–83. Operation. The probe is supplied with an integral straight tip. It may be used with its ground lead connection to 100 MHz. Additionally, a retractile hook-tip is provided for convenience. For optimum accuracy above 10 MHz, the coaxial BNC adapter sleeve should be used. No ground lead is required when using the BNC adapter. The adapter is slipped onto the probe barrel and fits into any BNC female connector. The probe should always be used in a terminated system. The Ballantine Model 12630A 50-ohm BNC feed-thru termination is recommended.
Maximum input voltage to the probe is 30 V rms or ±200 V dc. The 30-volt ac level is additive and must be combined with the dc limit so as not to exceed ±200 volts peak.

CAUTION

DC input level changes greater than ±200 volts will damage the probe.

The Ballantine Model 10851A RF High Voltage Probe Kit is available for measurements to 500 V rms and 1 GHz. Take care to avoid ground current and common mode voltage measurement errors. Use battery off-line operation and/or check the effects of earth grounding the COMMON connector of the DMM.

7–84. Voltage Measurement of CW or FM Sine Wave Signals.

a. Connect the 10850B probe termination to the V-Ω and COMMON inputs of the DMM. Make sure the red-marked (HI) banana plug is connected to the V–Ω connector.

b. Attach the required probe tip, BNC adapter, and termination. Connect the probe to the circuit point to be measured.

c. Push the DMM pushbutton switches S1 to ON, S2 to DC, and S3 to V.

d. Select the desired voltage range: 200m, 2, or 20.

e. Note the display, which reads in volts rms.

7–85. Demodulation Measurement of AM Signal On High-frequency Carrier.

a. Connect the 10850B probe termination to the V-Ω and COMMON inputs of the DMM. Make sure the red-marked (HI) banana plug is connected to the V–Ω connector.

b. Attach the required probe tip, BNC adapter, and termination. Connect the probe to the circuit point to be measured.

c. Push the DMM pushbutton switches S1 to ON, S2 to AC, and S3 to V.

d. Select the desired range: 200m, 2, or 20.

e. Make sure the AM frequency is within the range of 50 Hz to 20 kHz, that the amplitude is stable and that the carrier frequency is between 100 kHz and 700 MHz.

f. The digital display will show the rms voltage of the carrier.

7–86. Calibration. The Model 10850B RF Probe is normally calibrated at 1 MHz. An ac voltage calibrator, such as the Fluke Model 5200, may be used to set the calibration with the trim potentiometer provided in the probe termination box. No high-frequency calibration is required. Proceed as follows:

a. Connect the 10850B probe to the V–Ω and COMMON inputs of the instrument.

b. Remove the four screws and cover from the probe termination housing.

c. Connect the 10850B probe to an ac voltage calibrator, such as the Fluke Model 5200. Set the Calibrator output to 1 volt rms at 1 MHz.

d. Push the DMM pushbutton switches S1 to ON, S2 to AC, S3 to V, and S8 to 2.

e. Adjust the trim potentiometer with an insulated screwdriver until the instrument display reads .998 to 1.002.

f. If desired, check the probe at 250 mV rms, 10 V rms, and 25 V rms inputs to obtain an indication of linearity which must provide an output of 0.75 to 1.3 with the probe calibrated at 1 volt.

g. Replace the probe termination cover and the four screws.

7–87. High-Frequency Calibration. Should high frequency calibration be required to check frequency response of the probe, very specific test equipment is required to generate a high frequency voltage source directly at the input tip of the probe without intervening lead lengths, connector or coaxial cables which cause mismatch errors. The source must be low in impedance to minimize the capacitive loading by the probe. A Model 440 micropotentiometer with 22 ohm coaxial resistor is required test equipment. Although a 1 volt rms test level is recommended a 0.5 volt level is acceptable when the rf power capability is not available to drive the 22 ohm coaxial micropot resistor to 1 volt levels. Use a Micropotentiometer with a 50 mA thermalelement for 0.5 volt amplitudes.

a. Test Set-up. Set-up the micropot to be driven from a 1 MHz, 10 MHz, 100 MHz, 270 MHz and 470 MHz sources having low harmonic distortion levels. Fit the coaxial probe tip BNC adapter sleeve to the RF Detector probe and insert it fully into the exposed "N" connector of the 22 ohm coaxial micropot resistor. Use a Ballantine 1610A Control unit as a Lindeck potentiometer control for the micropotentiometer thermalelement output or use a dc digital voltmeter with 10 microvolt resolution to monitor the thermalelement output voltage. Connect a dc voltmeter such as the Ballantine 3028B DMM set to the 2 volt dc range to the output of the RF Detector Probe under test.

b. Test Procedure

1. Apply 1 MHz to the micropot and carefully increase the ac signal until the probe readout dc digital meter indicates 1.000 ± .008 volts (or 0.500 ± .005 when using half volt levels).

2. Note the output of the Model 440 micropotentiometer thermalelement voltage or null the Lindeck potentiometer when using the Model 1610A Control Unit.

3. Change the input frequency to 10 MHz and reset the ac input level to provide the same micropotentiometer thermalelement output noted in step b.

4. The probe readout DVM should read within .950 and 1.050 (0.475 and 0.525).

5. Repeat step c at 100 MHz input. The probe readout DMM should read within the limits of 0.940 and 1.060 (0.470 and 0.530).

6. Repeat step c with 270 MHz input. The probe readout DMM should read within the limits of 0.890 and 1.110 (0.445 to 0.555).

7. Repeat step c with 470 MHz input. The probe readout DMM should read within the limits of 0.700 and 1.300 (0.350 and 0.650).

NOTE

The above test procedure and limits require the test equipment specified. Use of any other test set-up and equipment will not provide verification of probe performance within the stated limits.

7–88. Schematic Diagram. A schematic diagram of the Model 10850B RF Detector Probe is shown in Figure 7–16.

7–89. Parts List. The probe is sealed and the entire probe must be replaced when the demodulator probe head is faulty. Replaceable parts are listed in Table 7–9.

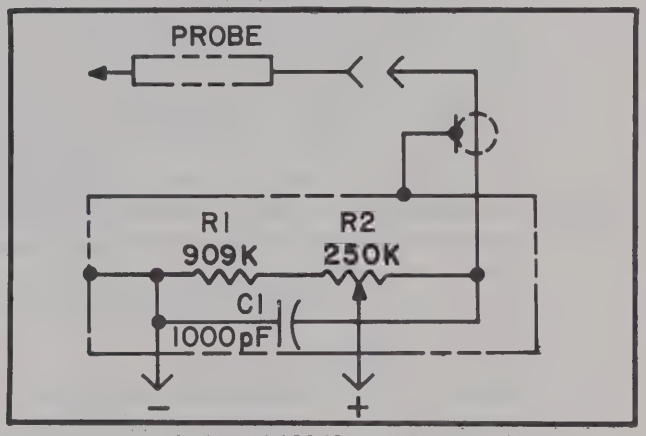


Figure 7–16. Model 10850B RF Detector Probe, Schematic Diagram

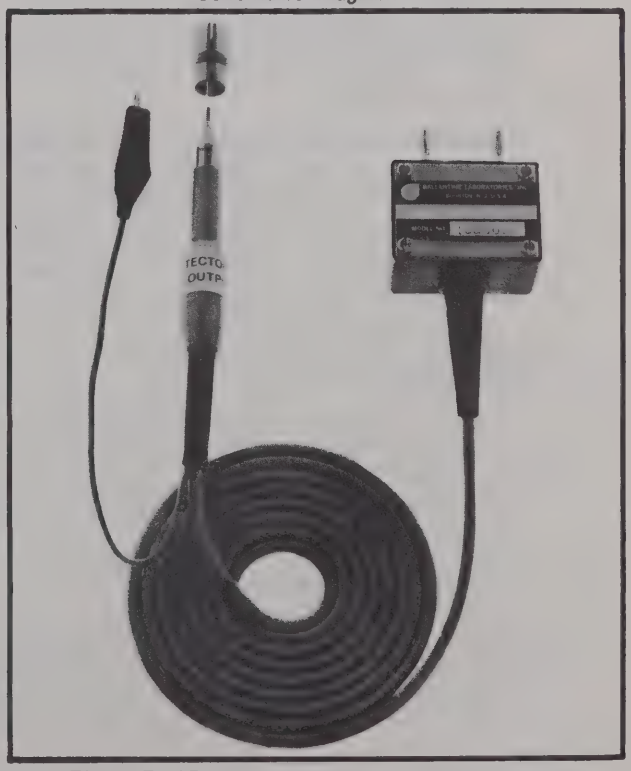


Figure 7–15. Model 10850B RF Detector Probe

TABLE 7–9. PARTS LIST, RF DETECTOR PROBE MODEL 10850B

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
C 1	07025920A	CCD 1.0 NF 1.0 KV K+-10%	84171	ARCO TYPE CCD-102
R 1	12125920A	RFF 909.0K 500.0MW F+-1%	16299	CGW RN60D 9093 F
R 2	09102300A	RVF 250.0K 250 0MW K CER.	0	HELIPOT 72XW VERT MT
---	85100580A	PROBE AND CABLE ASSEMBLY	50423	BLI

7–90. CURRENT PROBE, AC, CLAMP-ON MODEL 10860A.

7–91. General. The Ballantine Model 10860A AC Current Probe extends the ac current measuring capability of Digital Multimeters. The probe covers a current range from 2 to 600 amperes. Frequency coverage is from less than 50 Hz to greater than 400 Hz. Nominal accuracy is ± 3% at 60 Hz. A voltage limiter is incorporated in the current probe to protect the operator against electric shock and limits the output voltage to 2.4 volts peak to peak irrespective of the test current magnitude or DMM current range selected. The clamp-on feature allows ac currents to be measured without breaking into the leads of the circuit under test. The effect of moving the current conductor from the center to any position within the core jaws is less than 3%.

7–92. Specifications.

Frequency Range: < 50 Hz to > 400 Hz.

Current Range: 2 Amperes to 600 Amperes Sinusoidal Current.

Accuracy: Entire range ± 3% of Full Scale used. Calibrated at 60 Hz, with current conductor centered.

Frequency Response:

> 25 Amperes, 50 to 400 Hz: ± 3% of Full Scale.

> 15 Amperes, 50 to 400 Hz: ± 4% of Full Scale.

> 10 Amperes, 50 to 400 Hz: ± 10% of Full Scale.

Conductor Position: The effect of moving the current conductor from center to any position within the tightly closed core jaws is < 3%.

Test Conductor Size:

Round Wires Diameter to 38 mm (1.5 inch).
Rectangular and Square Conductors to 38 mm (1.5 inch) cross section.
Foils and Sheets with maximum thickness of 2.8 mm (0.11 inch) and 1.8 inches wide.

Insulation: Insulation of probe housing is designed for operation to 650 volts rms at 60 Hz.

Safety: To protect the operator against shock, an overvoltage limiter on the output connections limits terminal voltage to 2.4 volts peak to peak irrespective of test current or load.

Connector: Dual banana plugs spaced 1.9mm (0.75 inch).

7–93. Operating Instructions.

WARNING

The clamp-on probe housing is made of high quality insulation and designed to provide long service under stress of frequent usage. EXERCISE EXTREME CARE WHEN MEASURING HIGH CURRENTS AND WHEN CLAMPING ON WIRES OR APPLIANCES CARRYING HIGH POWER LINE VOLTAGES.
NEVER USE THE PROBE WHEN THE INSULATING MATERIAL OR THE HOUSING IS DAMAGED OR WHEN THE MAGNETIC CORE MAY COME IN CONTACT WITH HIGH VOLTAGES.

7–94. Use the following procedure for operating the Model 10860A AC Clamp-On Current Probe with the 3028 Series of Digital Multimeters.

a. Plug the 10860A dual banana termination into the A and COMMON terminals of the DMM.

b. Push in the A pushbutton to select the current function.

c. Select ac operation. The 10860A can be used on sinusoidal and distorted ac signals so that the rms responding detectors of the 3028 Series will provide improved accuracy of measurement.

d. Select the DMM Current Range as indicated below.

DMM Range	Measurement Range With 10860A Probe
20 mA	2A to 20A
200 mA	20A to 200A
2000 mA	200A to 600A

e. Clamp the probe around the current carrying conductor to be measured. Center the conductor within the core jaws. Make sure jaws are firmly closed and in full contact.

Note

Clamping the probe around more than one current carrying conductor at a time produces a reading on the DMM which is the vector sum of the currents in each of the conductors.

f. Read the DMM. It is indicating the measured current in Amperes.

7–95. MAINTENANCE.

7–96. The Model 10860A is a rugged instrument designed for long life in every day service. The high quality plastic housing must be checked for damage to avoid electrical contact with the magnetic jaws. Avoid solvents or vapors which may attack the plastic. Clean with water and mild detergents.

7–97. Keep the magnetic surfaces of the jaw mating surfaces clean and free from dust, wire insulation or other dirt. The clamp-on probe functions only with completed mating jaws to hold the magnetic reluctance to a minimum and assure accuracy and repeatability of all current measurements.

7–98. The probe is not field calibratable and depends on the transformer current ratio for accuracy.

7–99. CHECKING THE OVER-VOLTAGE LIMITER.

a. Connect the current probe to the V-Ω and COMMON inputs of the DMM. Set the function for ac voltage on the 2 volt range.

b. Clamp the current probe jaws on a conductor carrying more than 50 amperes.

c. The voltage indicated on the DMM must not exceed 1.9 volts or the four current limiting diodes in the probe termination must be replaced. Use 3 ampere rated 50 volt diodes such as 1N5400 Ballantine P/N 05100630A.

7–100. CURRENT PROBE, AC, CLAMP-ON MODEL 10861A.

7–101. General. The Ballantine Model 10861A AC Current Probe extends the ac current measuring capability of Digital Multimeters. The probe covers a current range from 2 to 150 amperes. Frequency coverage is from less than 40 Hz to greater than 400 Hz. Nominal accuracy is ± 3% at 60 Hz. A voltage limiter is incorporated in the current probe to protect the operator against electric shock and limits the output voltage to 2.4 volts peak to peak irrespective of the test current magnitude or DMM current range selected. The clamp-on feature allows ac currents to be measured without breaking into the leads of the circuit under test. The effect of moving the current conductor from the center to any position within the core jaws is less than 3%.

7–102. Specifications.

Frequency Range: < 40 Hz to > 400 Hz.

Current Range: 2 Amperes to 150 Amperes Sinusoidal Current.

Accuracy: ± 4% of Full Scale used. Calibrated at 60 Hz, with current conductor centered.

Frequency Response:

> 20 Amperes, 40 to 400 Hz: ± 3% of Full Scale.

> 10 Amperes, 40 to 400 Hz: ± 4% of Full Scale.

> 2 Amperes, 40 to 400 Hz: ± 10% of Full Scale.

Conductor Position: The effect of moving the current conductor from center to any position within the tightly closed core jaws is < 3%.

Test Conductor Size:

Round Wires Diameter to 12 mm (.48 inch).

Rectangular and Square Conductors to 6.4 mm (.25 inch) cross section.

Foils and Sheets with maximum thickness of 2.8 mm (0.11 inch) and 1.8 inches wide.

Insulation: Insulation of probe housing is designed for operation to 650 volts rms at 60 Hz.

Safety: To protect the operator against shock, an overvoltage limiter on the output connections limits terminal voltage to 2.4 volts peak to peak irrespective of test current or load.

Connector: Dual banana plugs spaced 1.9 mm (0.75 inches).

7–103. Operating Instructions.

WARNING

The clamp-on probe housing is made of high quality insulation and designed to provide long service under stress of frequent usage. EXERCISE EXTREME CARE WHEN MEASURING HIGH CURRENTS AND WHEN CLAMPING ON WIRES OR APPLIANCES CARRYING HIGH POWER LINE VOLTAGES.

NEVER USE THE PROBE WHEN THE INSULATING MATERIAL OR THE HOUSING IS DAMAGED OR WHEN THE MAGNETIC CORE MAY COME IN CONTACT WITH HIGH VOLTAGES.

7–104. Use the following procedure for operating the Model 10861A AC Clamp-On Current Probe with the 3028 Series of Digital Multimeters.

a. Plug the 10861A dual banana termination into the A and COMMON terminals of the DMM.

b. Push in the A pushbutton to select the current function.

c. Select ac operation. The 10861A can be used on sinusoidal and distorted ac signals so that the rms responding detectors of the 3028 Series will provide improved accuracy of measurement.

d. Select the DMM Current Range as indicated below.

DMM Range	Measurement Range with 10861A Probe
20 mA	2A to 20A
200 mA	20A to 150A

e. Clamp the probe around the current carrying conductor to be measured. Center the conductor within the core jaws. Make sure jaws are firmly closed and in full contact.

Note

Clamping the probe around more than one current carrying conductor at a time produces a reading on the DMM which is the vector sum of the currents in each of the conductors.

f. Read the DMM. It is indicating the measured current in Amperes.

7–105. HIGH VOLTAGE RF DETECTOR PROBE, MODEL 10851A.

7–106. General. The Model 10851A RF Probe is a sturdy probe, capable of operation to beyond 1200 MHz and at voltages to 30 volts rms. A capacitive divider is supplied to extend the input voltage to 500 V rms. The probe body is sized for 50 ohm Type N connector accessories and accommodates various accessories including a 100:1 Capacitive divider, and an optional non-loading 50 ohm Tee adapter.

7–107. Specifications.

Usable Frequency Range: < 20 kHz to > 1200 MHz

AC to DC Transfer Accuracy:

(Input from 50Ω coaxial system; Output into 10 MΩ; + 20°C to + 30°C)

± .5 dB 50 kHz to 200 MHz
± 1.0 dB 200 MHz to 500 MHz
± 1.5 dB 500 MHz to 1000 MHz

Specification applicable with Model 5340A Tee adapter for measurements above 100 MHz.

Operating Voltage Range: Sinusoidal inputs

220 mV to 30V rms Probe alone
22V to 500V rms Probe with 1340A divider

Maximum Input Voltage: (limit of 5×10^9 rms volt hertz):

Probe – 43V peak; ± 400 DC

Probe with Model 1340A Divider: 700 V AC peak; ±500 V DC (absolute maximum)

Input Impedance:

Probe – ≃3 pF shunted by ≃100 KΩ

Probe with 1340A Divider – ≃ 4.5 pF shunted by > 10 MΩ

Response: Peak detector calibrated in rms of a sine wave from 220 mV to 30V for the probe and 22V to 500 volts for the probe with Model 1340A divider.

Calibration: Probe may be calibrated with ± 1% of nominal from 1 MHz to 100 MHz sinusoidal input from 50 ohms. Factory calibration is performed at 1 volt rms and 1 MHz. Model 1340A capacitive divider is factory calibrated for division ratio of ± 1% at 1 MHz.

Cable Length: 1.5 meters (5 feet)

ACCESSORIES SUPPLIED:

Model 10851A Probe Assembly

Model 1340A 100:1 Capacitive Voltage Divider

Model 4340A Adapter, tip

OPTIONAL ACCESSORIES:

Model 2340A Adapter, Coaxial "N" and BNC Male Connector

Model 5340 Adapter, non-loading "Tee" for 50 ohm lines; mates with Type "N" Connectors.

P/N 31-10189-0A Termination "N" Precision 50 ohm, 1 watt VSWR less than 1.2 to 1 GHz. Use with model 5340A "Tee" Adapter.

Model 6340A 50 ohm, 1 watt Feed Thru Probe Termination, Coaxial "N" and BNC Male Connector, usable to 600 MHz.

7–108. AC AVERAGE RESPONDING 100 kHz BANDWIDTH, OPTION 24H

7–109. General. Option 24H is a modification of the standard option 24 detailed in paragraph 7–46. Option 24H extends the frequency range to 100 kHz with average response calibrated in rms of a sine-wave. It includes improved linearity for low level signals at higher frequencies and deletes the 20 mV, 20 ohm and 20 μA ranges of the standard 3028B. In addition the ohmmeter circuit is modified to limit maximum, open circuit voltage to less than 5 Volts in both the HIΩ and LOΩ functions.

7–110. Specifications.

- **DC Voltage and Current** specifications listed in paragraph 1–9 remain unchanged except that the 20 mV and 20 μA ranges are deleted.

- **Ohmmeter** specifications listed in paragraph 1–9 remain unchanged except that the 20 ohm range is deleted.

  Maximum ohmmeter open circuit voltage in HIΩ and LOΩ mode is 5 Volts.

- **AC VOLTAGE**

Range	Maximum Scale	Resolution
200 mV	199.9 mV	100 μV
2 V	1.999 V	1 mV
20 V	19.99 V	10 mV
200 V	199.9 V	100 mV
1000 V	1000 V	1 V

Accuracy (Sine-wave): 1 year, 15°C to 35°C Frequency Response (referenced to 400 Hz); Usable < 20 Hz to > 150 kHz.

	1 Year
45 Hz to 10 kHz	± (0.5% of reading + 1LSD)
10 kHz to 20 kHz	± (1% of reading + 1LSD)
20 kHz to 100 kHz	± (3% of reading + 1LSD)

Response: Average responding. Calibrated in rms of a sine-wave.

Temperature coefficient:

−10°C to +15°C and 35°C to 55°C
± (0.01% of reading/°C +0.005% of full scale/°C)

Input Impedance:

10 Megohms in parallel with less than 100 pF on all ranges.

Common Mode Rejection:

(1 kΩ unbalance with COMMON driven) Greater than 110 dB at DC and 60 dB at 50 Hz or 60 Hz. 110 dB at 60 Hz with internal battery operation.

DC Blocking Voltage (Normal Mode): ±1200 Volts dc maximum.

Maximum Input Voltage:

1200 V dc plus peak ac sinusoidal on all ranges. Must not exceed 10^8 Volt-Hz.

Response Time: 3 seconds (typically 1 second) within any one range.

- **AC CURRENT**

Range	Max. Scale	Resolution	Input Resistance
200 μA	199.9 μA	100 nA	1000 Ω
2 mA	1.999 mA	1 μA	100 Ω
20 mA	19.99 mA	10 μA	10.1 Ω
200 mA	199.9 mA	100 μA	1.15 Ω
2000 mA	1.999 mA	1 mA	0.25 Ω

Response: Average responding. Calibrated in rms of a sine-wave.

Accuracy: 1 year, 15°C to 35°C

	1 Year
2000 mA range 45 Hz to 3 kHz, all other ranges 45 Hz to 10 kHz	± (1% of reading + 1LSD)
	± (1% of reading + 1LSD)

Temperature Coefficient:

−10°C to 15°C and 35° to 55°C
± (0.015% of reading/°C & 0.005% of full scale/°C)

Voltage Burden at Full Scale:

0.25 Volts maximum on all ranges except 0.5 Volts on the 2000 mA range.

Maximum Input:

2 amperes (dc + ac rms). Protected by resettable circuit breaker and diode clamps to 15A peak current.

Response Time:

3 seconds within any one range.

7–111. Operation.

7–112. The 3028B option 24H multimeter responds to the average of the ac input signal and is calibrated in rms of an undistorted sine-wave input. If the input voltage is not sinusoidal, the resulting measurement error may be considerable. The amount of error depends upon the number and percentage of harmonics present as well as their phase relationships. RMS calibration is used since rms gives the true measure of the power capability or heating value of the input waveform.

7–113. Ballantine offers other instruments such as the Model 3620A and the standard 3028B which respond to the true rms of the input waveform. A true rms instrument should always be used to measure ac voltages which have considerable harmonic content or nonsinusoidal voltages such as may be found in ac/dc rectifiers, SCR devices, pulse trains, square waves, inductive loads, power measurements, and noise measurements.

7–114. An unknown voltage which is not sinusoidal may be displayed and analyzed on an oscilloscope. However, a meter cannot give an indication of this kind, and the user cannot know from a digital or analog voltmeter presentation what distortion might be present in the signal under test.

7–115. AC signals are often highly distorted and the operator must consider that ac measurement accuracies are specified for sinusoidal signals. Errors may be identified through Table 7–5. The 3028B, Option 24H is average responding and calibrated in rms of a sine-wave.

7–116. All other ac measurement conditions listed in Section 3 of this manual are applicable to the 3028B, Option 24H.

7–117. THEORY OF OPERATION

7–118. All of the discussion in Section 4 is applicable to the 3028B Opt. 24H.

7—119. AC to DC Converter (Reference Designator 400 Series). The ac-to-dc converter takes the ac input signal from the input voltage divider or the current shunts and converts it into a dc voltage. This dc voltage is then measured by the dc voltage analog-to-digital converter. The ac-to-dc converter is a wideband circuit operating from <20 Hz to beyond 150 kHz and over a dynamic range of 100 μ V to beyond 2 volts rms. See Figure 7—17 for a simplified diagram of the ac converter.

7—120. The input to the ac converter consists of field effect transistor Q400. This dual gate MOSFET is connected with PNP Q401 to provide high-input impedance and low-output impedance. It has internal diode protection for input overloads. Resistor R400 is the voltage-dropping resistor which limits the FET input current to avoid damage during overloads.

7—121. The input FET follower (Q400) and transistor (Q401) drive the noninverting input of operational amplifier U400. Diode CR401 protects the input of U400 from overloads. Feedback from the output of U400 to its inverting input causes the operational amplifier output to follow the input signal from FET follower Q400. This results in a current flow from ground through R408 plus R409 which is equal to E in/(R408 + R409). Diodes CR402 and CR403 conduct on alternate cycles of the input ac waveform. Therefore, one-half the average current flows through R406. The ac-to-dc converter is an operational full-wave rectifier and the voltage at the junction of CR403 and R406 is sent through low-pass filter R411 and C410 for measurement by the dc analog voltage-to-digital converter. The detector responds to the average of the ac signal input and is calibrated in rms of a sine-wave. R413 improves low amplitude linearity and frequency response.

7—122. The Option 24H ohmmeter circuit has been modified to limit the open circuit ohmmeter voltage to a maximum of 5 Volts.

7—123. The reference designators in the 350 sequence define the components added to sense overvoltage and then switch U300 the ohmmeter current source operational amplifier to limit output voltage.

7—124. The ohmmeter provides a negative going dc voltage. CR601 senses the maximum voltage at the input terminals through R600 and turns off Q351. The collector of Q351 then rises toward +12 Volts and raises the voltage at the emitter of Q352 which shuts down the ohmmeter constant current source consisting of Q300, Q301 and Q302. When the current supplied by Q300 decreases the voltage output at pin 6 of U300 is limited to provide no more than 5 Volts open circuit ohmmeter voltage. The ohmmeter circuit returns to its normal calibrated state as soon as an external resistance across V-Ω and COMMON brings the ohmmeter within required "on scale" measurement range.

7—125. Calibration.

7—126. The AC to DC converter calibration R409 and all other AC input attenuator calibrations are performed as detailed in Section 5. To check calibration accuracy refer to Table 7—10.

TABLE 7—10. AC VOLTAGE ACCURACY, OPTION 24H.
(COMMON tied to earth ground lug on rear panel)

AC Voltage Calibrator			DMM
Voltage	Frequency	Range	Display Limits
0000 mV	500 Hz	200 m	00.0 to 00.5
20.00 mV	500 Hz	200 m	19.7 to 20.3
190 mV	500 Hz	200 m	188.9 to 191.1
190 mV	50 kHz	200 m	184.1 to 195.9
1.900 V	500 Hz	2	1.889 to 1.191
1.900 V	5 kHz	2	1.889 to 1.911
1.900 V	50 kHz	2	1.841 to 1.959
1.900 V	100 kHz	2	1.841 to 1.959
19.00 V	500 Hz	20	18.89 to 19.11
19.00 V	50 kHz	20	18.41 to 19.59
190.0 V	500 Hz	200	188.9 to 191.1
190.0 V	50 kHz	200	184.1 to 195.9
1000.0 V	500 Hz	1200	993 to 1007
1000.0 V	50 kHz	1200	968 to 1032

7–127. The ohmmeter calibration is not affected by the voltage limit modification and calibration is detailed in Section 5.

7–128. Schematic and Parts List.

7–129. Figure 6-3 is a schematic diagram of the 3028B Option 24H.

7–130. The parts list shown in Section 6 is applicable for Option 24H with the following changes.

a. Delete R408 (909Ω) R410 (2.61 k) C702 (22 μF) R305 (4.7k) C409 (300 pF) RN701 (7 x 47Ω)

b. Add the following components shown in Table 7–11.

TABLE 7–11. PARTS LIST, OPTION 24H

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
C.351	07-10198-0A	CCD 100.0NF 25.0 V NPO	56289	SPRAG C069A250M1042 OR EQ
C.409	07-10497-0A	CMD 270.0PF 300.0 VF	84171	ARCO TYPE CM05DC271F01
CR351	05-10034-0A	DZG IN 749A 4.3 20M .4	4713	MOT SI
CR402	05-09462-0A	DGP 5082-2800 70	28480	HPA SCHOTTKY 2
CR403	05-09462-0A	DGP 5082-2800 70	28480	HPA SCHOTTKY 2
CR601	05-10103-0A	DXS PAD50 35.0V .50M	17856	SIL PAD50 PICOAMP 51
Q.351	10-09485-0A	TRQ MPS6521 NPN 1 25 PTO-92	4713	MOT 1 390M 100
Q.352	10-09473-0A	TRQ 2N3906 PNP 1 40 PTO-92	4713	MOT 1 200M 60
R.351	12-08020-0A	RFC 10.0 M 250.0MW J+-5%	1121	A-B TYP CB
R.352	12-12500-0A	RFF 100.0 K 250.0MW F+-1%	16299	CGW RN55D 1003 F
R.353	12-12388-0A	RFF 8.25 K 250.0MW F+-1%	16299	CGW RN55D 8251 F
R.354	12-12384-0A	RFF 7.50 250.0MW F+-1%	16299	CGW RN55D 7501 F
R.408	12-12288-0A	RFF 825.0 250.0MW F+-1%	16299	CGW RN55D 8250 F
R.410	12-12364-0A	RFF 4.64K 250.0MW F+-1%	16299	CGW RN55D 4641 F
R.413	12-12904-0A	RFC 100.0 M 250.0MW +-10%	1121	AB-TYPE CB

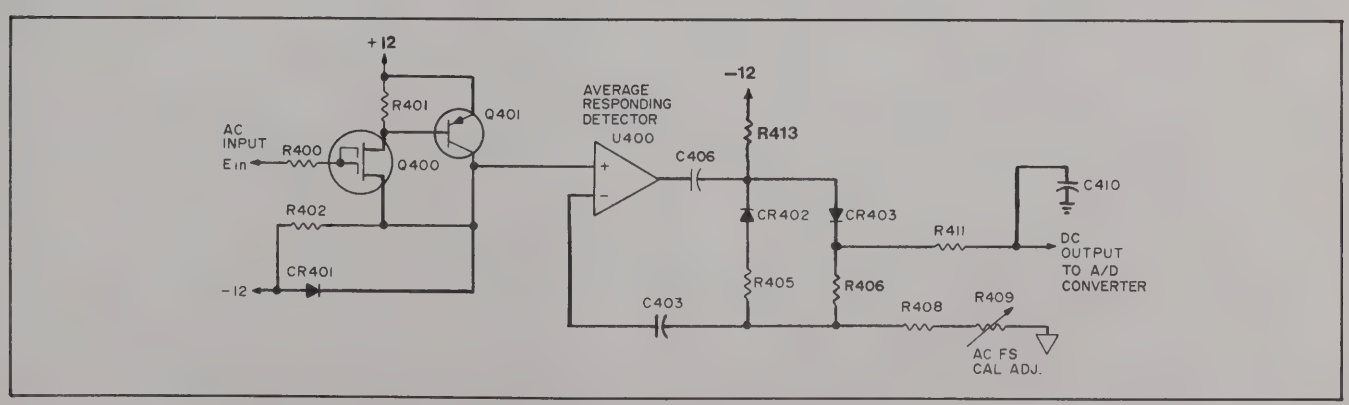


Figure 7–17. AC Converter, Simplified Diagram — Option 24H.

SECTION 8

BACKDATING INFORMATION

Applicable To Units With
Serial Prefix No. 050 – And Below

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
C 100	07103360A	CBM 47.0NF 1.6KV +-10%	80031	MEPCO C281/1600/A47K
C 101	07104501A	CTE 3.0PF 1.2KVJ	50423	
C 102	07103500A	CMD 470.0PF 500.0 V TCE 2%	84171	ARCO DM15ED470G03 ARCO
C 103	07103600A	CVC 10-60PF 350.0 V N750	50423	
C 104	07201350A	CMD 22.0PF 5%	84171	DM15-220J OR EQUIV.
C 105	07103540A	CMD 1.0NF 500.0 V +- 1%	84171	ARCO DM-19-F-D-1000-F-N-U
C 106	07101170A	CMD 12.0PF 500.0 VJ 1%	84171	ARCO DM-15-C-120 JN
C 107	07105701A	CVE 1.2PF 1.2KVJ	50423	
C 110	07103600A	CVC 10-60PF 350.0 V N750	50423	
C 300	07101370A	CMD 160. PF 500. VJ	72136	ELMENCO DM15ED161J03
C 301	07101370A	CMD 160. PF 500. VJ	72136	ELMENCO DM15ED161J03
C 302	07200940A	CCD 100.0 NF 25.0V +-20%	91418	M25-1
C 401	07101200A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C 403	07103410A	CBM 470.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A470K
C 404	07101200A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C 406	07102580A	CET 68.0UF 15.0 VK DIP TAN	56289	SPRAG 196D686X9015-LA3
C 407	07101790A	CET 22.0UF 15.0 VM	56289	SPRAGUE 196D226X0015KE3
C 408	07101790A	CET 22.0UF 15.0 VM	56289	SPRAGUE 196D226X0015KE3
C 409	07100870A	CMD 390.0PF 100.0 VIJ	84171	ARCO RDM-15-391J
C 410	07103410A	CBM 470.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A470K
C 501	07103410A	CBM 470.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A470K
C 502	07101200A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C 503	07101200A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C 600	07103370A	CBM 68.0NF 630.0 V +-10%	80031	MEPCO C280MCG/A68K
C 601	07103380A	CBM 33.0NF 400.0 V +-10%	80031	MEPCO C280MCF/A33K
C 602	07101200A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C 603	07103390A	CBM 100.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A100K
C 604	07101200A	CCD 22.0 NF 25.0 VM	71590	CENTRLB UK25223
C 605	07101200A	CCD 22.0 NF 25.0 VM	71590	CENTRLB UK25223
C 606	07104410A	CBM 10.0NF 400.0 V	80031	MEPCO C280MCF/A10K
C 700	07104390A	CEA 100.0UF 6.3 V		CAPAR CRE 100UF/6.3V
C 701	07101790A	CET 22.0 UF 15.0 VM	56289	SPRAGUE 196D226X0015KE3
C 702	07102580A	CET 68.0 UF 15.0 VK	56289	SPRAGUE 196D686X9015LA3
C 703	07101790A	CET 22.0 UF 15.0 VM	56289	SPRAGUE 196D226X0015KE3
C 800	07103380A	CBM 33.0NF 400.0 V +-10%	80031	MEPCO C280MCF/A33K
C 801	07103380A	CBM 33.0NF 400.0 V +-10%	80031	MEPCO C280MCF/A33K
C 802	07104400A	CEA 1000 UF 16.0 V		CAPAR CRE 1000UF/16V
C 803	07104400A	CEA1000.0UF 16.0 V		CAPAR CRE 1000UF/16V
C 804	07104400A	CEA1000.0UF 16.0 V		CAPAR CRE 1000UF/16V
C 805	07101200A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C 806	07101200A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C 807	07101200A	CCD 22.0NF 25.0 VM	71590	CENTRLB UK25223 OR EQUIV
C 900	07104470A	CEA2200.0UF 16.0 V		CAPAR CRE 100UF/6.3V
CB 10	19100351E	CBK 2A BREAKER FAST	50423	
CR 200	05100630A	DRP 1N5400 50 3A	04713	MOT SI
CR 201	05100630A	DRP 1N5400 50 3A	04713	MOT SI
CR 202	05100630A	DRP 1N5400 50 3A	04713	MOT SI
CR 203	05100630A	DRP 1N5400 50 3A	04713	MOT SI
CR 300	05094770A	DZG 1N5231 5.1 .5W	04713	MOT SI DO7
CR 301	05100990A	DZG 1N5243A 13.0VJ .5W	04713	MOT 1N5243A 13V ZENER
CR 401	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
CR 402	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
CR 403	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
CR 500	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
CR 602	05101030A	DXS PAD-50 35.0V .50M	17856	SILICONIX PAD-50
CR 800	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
CR 801	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
CR 802	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035
CR 803	05079200A	DGP 1N4148 75 10M	07263	FCH SI D035

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
CR 900	05080580A	DGP 1N4006 400 1A	15238	ITT SI D046
CR 901	05080580A	DGP 1N4006 400 1A	15238	ITT SI D046
DS 750	21100400A	IND 0.43 IN HI EFF.RED C.C	28480	HP 5082-7653 COMMON CAT.
DS 751	21100400A	IND 0.43 IN HI EFF.RED C.C	28480	HP 5082-7653 COMMON CAT.
DS 752	21100400A	IND 0.43 IN HI EFF.RED C.C	28480	HP 5082-7653 COMMON CAT.
DS 753	21100410A	IND 0.43 IN.HIEF.RED CC +-1	28480	HP 5082-7656 COMMON CAT.
F 50	19100360A	FUS .125A NORMAL-BLO	75915	LITTELFUSE TYP3AG NORMBLO
J 1	31301260A	CON FLEXPRINT 20 PINS PC MT	26394	ANSLEY 609 2003
J 1A	31301270A	ADA ADAPTER FOR 31301260A	26394	ANSLEY 609-W208
J 10	31101320A	BPS 10MM GREY	50423	
J 20	31101320A	BPS 10MM GREY	50423	BLI
J 30	31101330A	BPS 10MM BLACK	50423	BLI
J 50	31100000A	REC AC POWER	82389	SWITCHCRAFT
L 10	46100030A	FRB FER BD CERAMAG 24	78488	STACKPOLE 571355
L 20	46100030A	FRB FER BD CERAMAG 24	78488	STACKPOLE 571355
L 30	46100030A	FRB FER BD CERAMAG 24	78488	STACKPOLE 571355
Q 300	10094730A	TRQ 2N3906 PNP 1 40 PTO-92	04713	MOT 1 200M 60
Q 301	10094730A	TRQ 2N3906 PNP 1 40 PTO-92	04713	MOT 1 200M 60
Q 302	05100761B	DZG 2N4274 6.8V 1.5M+-10%	50423	BLI
Q 302	05100763B	DZG 2N4274	50423	
Q 400	10101051A	TRQ 40673 SEL FOR LEAK	50423	
Q 401	10094730A	TRQ 2N3906 PNP 1 40 PTO-92	04713	MOT 1 200M 60
Q 600	10100990A	TRQ E507	17856	SILICONIX
Q 601	05100761B	DZG 2N4274 6.8V 1.5M+-10%	50423	BLI
Q 602	10101280A	TRQ E111 N J FET TO-106	17856	SILICONIX E111 RDS=30OHM
Q 603	10101300A	TRQ E108 N J FET TO-106	17856	SILICONIX E108 RDS=80HMS
Q 700	10094730A	TRQ 2N3906 PNP 1 40 PTO-92	04713	MOT 1 200M 60
Q 800	10100870A	TRQ 2N5193 PNP 1 40 P7703	04713	MOT 40 2M 10
Q 801	10100870A	TRQ 2N5193 PNP 1 40 P7703	04713	MOT 40 2M 10
R 100	12128670A	RFF 9.76M 2.0 W 1%	03888	PYROFILM PME 64T9 2.5KV
R 101	09100090A	RVC 250.0 K 0.5 WK +-10%	73138	HEL TYP 72PM
R 102	12129370A	RFW 90.0 K 1.0 W .05%NI	50423	
R 104	12128610A	RFW 10.0 K 7.0 W 0.05%	50423	
R 105	12010950A	RFC 18.0 M 500.0MW J+- 5%	01121	A-B TYP EB
R 300	12123890A	RFF 8.45K 250.0MW FT- 1%	16299	CGW RN55D 8451 F
R 301	09100050A	RVF 1.00K 0.5 WK CERMET	73138	HELIPOT 72PM
R 302	12123000A	RFF 1.0 K 250.0MW FT- 1%	16299	CGW RN55D 1001 F
R 303	12123760A	RFF 6.19K 250.0MW FT- 1%	16299	CGW RN55D 6191 F
R 304	09100050A	RVF 1.00K 0.5 WK CERMET	73138	HELIPOT 72PM
R 305	12010480A	RFC 4.7 K 500.0MW J+- 5%	01121	A-B TYP EB
R 400	12128630A	RFC 150.0 K 2.0 W 5%	01121	A-B HB
R 401	12010570A	RFC 1.0 K 500.0MWJ +- 5%	01121	A-B TYP EB
R 402	12010440A	RFC 10.0K 500.0MW J+- 5%	01121	A-B TYP EB
R 404	12010070A	RFC 2.0 M 500.0MW J+- 5%	01121	A-B TYP EB
R 405	12123280A	RFF 1.91K 250.0MW FT- 1%	16299	CGW RN55D 1961 F
R 406	12123280A	RFF 1.91K 250.0MW FT- 1%	16299	CGW RN55D 1961 F
R 408	12122920A	RFF 909.0 250.0MW FT- 1%	16299	CGW RN55D 9090 F
R 409	09100040A	RVF 100.0 0.5 W M	73138	HEL TYP 72PM
R 410	12123400A	RFF 2.61K 250 MW F+-1%	16299	CGW RN55D 2611 F
R 411	12089580A	RCF 240.0 K 500.0MW J+- 5%	01121	A-B TYP EB
R 501	12123280A	RFF 1.91K 250.0MW FT- 1%	16299	CGW RN55D 1961 F
R 502	12010720A	RFC 39.0 500.0MW J+- 5%	01121	A-B TYP EB
R 503	12080210A	RFC 1.2 M 250.0MW J+- 5%	01121	A-B TYP CB
R 504	12098260A	RFC 4.7 M 250.0MW J+- 5%	01121	A-B TYP CB
R 505	12010500A	RFC 3.9 K 500.0MW J+- 5%	01121	A-B TYP EB
R 306	12125000A	RFF 100.0K 250.0MW F+-1%	16299	CGW RN55D 1003F

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
R 506	09100030A	RVC 100.0 K 0.5 WK +-10%	73138	HEL TYP 72PM
R 600	12128620A	RFC 560.0 K 2.0 W 5%	01121	A-B HB
R 601	12128730A	RFC 560.0 K 500.0MW	01121	A-B TYPE E-B
R 602	12010910A	RFC 27.0 K 500.0MW J+- 5%	01121	A-B TYP EB
R 603	12011380A	RFC 1.8 500.0MW K+-10%	01121	A-B TYP EB
R 604	09101460A	RVF 25.0 K 500.0MW TRIMPOT	73138	HELIPOT 72PM
R 605	09101460A	RVF 25.0 K 500.0MW TRIMPOT	73138	HELIPOT 72PM
R 606	09101070A	RVF 200.0 250.0MW K CER	73138	HEL TYPE 72PM-200
R 607	09100020A	RVC 5.0 K 0.5 WK +-10%	73138	HEL TYP 72PM
R 608	09100010A	RVC 500.0 0.5 W K	73138	HEL TYP 72PM
R 609	09100920A	RVF 50.0 K 500.0MW KVERT MT	73138	HELIPOT 72XW 50K
R 801	09101070A	RVF 500.0 0.5W K CER	73138	HEL TYPE 72PM-200
R 904	12129340A	RFC 3.3M 500 MW J+-5%	01121	A-B TYPE EB
RN 200	13100021A	RNW 3028A SHUNT RES,14DIP	50423	BLI
RN 600	13100401A	RNF 3028B 14 PIN DIP 1% RES.	50423	BLI
RN 601	13100421A	RNF 3028B 14 PIN DIP 1,5%RES	50423	BLI
RN 700	*13100961A	RNF 3028B 14 PIN DIP 5% RES.	50423	BLI
RN 701	*13100940A	RNF 69.0 14 PIN DIP 7 RES.	80053	BECKMAN 899-3-R68
RN 800	13100391B	RNF 3028B 8 PIN SIP 120/750	50423	BLI
S 1		SWC 3028B FUNCTION 6 STAT.	50423	BLI
S 2		SWC 3028B FUNCTION 6 STAT.	50423	BLI
S 3	25101441L	SWC 3028B FUNCTION 6 STAT.	50423	BLI
S 4		SWC 3028B FUNCTION 6 STAT.	50423	BLI
S 5		SWC 3028B FUNCTION 6 STAT.	50423	BLI
S 6		SWC 3028B FUNCTION 6 STAT.	50423	BLI
S 7		SWC 3028B RANGE 7 STAT.	50423	BLI
S 8		SWC 3028B RANGE 7 STAT.	50423	BLI
S 9		SWC 3028B RANGE 7 STAT.	50423	BLI
S 10	25101461L	SWC 3028B RANGE 7 STAT.	50423	BLI
S 11		SWC 3028B RANGE 7 STAT.	50423	BLI
S 12		SWC 3028B RANGE 7 STAT.	50423	BLI
S 70		SWC 3028B RANGE 7 STAT.	50423	BLI
T 800	20100291D	TRX 3028A DC/DC CONV.	50423	BLI
T 900	20100581Q	TRX 3028B POWER 120V ONLY	50423	BLI
U 300	24102120A	ICP CA3140S FET OP AMP TO-5	86684	RCA CA3140S TO-5 DU.JN.LN
U 400	24102130A	ICP LM318N FAST OP AMP	27014	NAT.SEMI DUAL IN LIN
U 500	24102120A	ICP CA 3140SFET OP AMP TO-5	86684	RCA CA3140S TO-5 DU.JN.LN
U 600	24102021A	ICP LD11A MODIFIED DVM.03%	50423	
U 700	24100941A	ICP DVM DIGITAL 3 1/2 DIGIT	17856	SILICONIX LD110 MODIFIED
U 701	24101880A	ICP 9667 7 DARLINGTON DRIVE	07263	FAIRCHILD 9667PC
U 702	24101960A	ICP 74C48 7 SEGMENT DRIVE		NATIONAL MM74C48N
U 900	24101530A	ICP UA7805 5V REG.	07263	FAIRCHILD

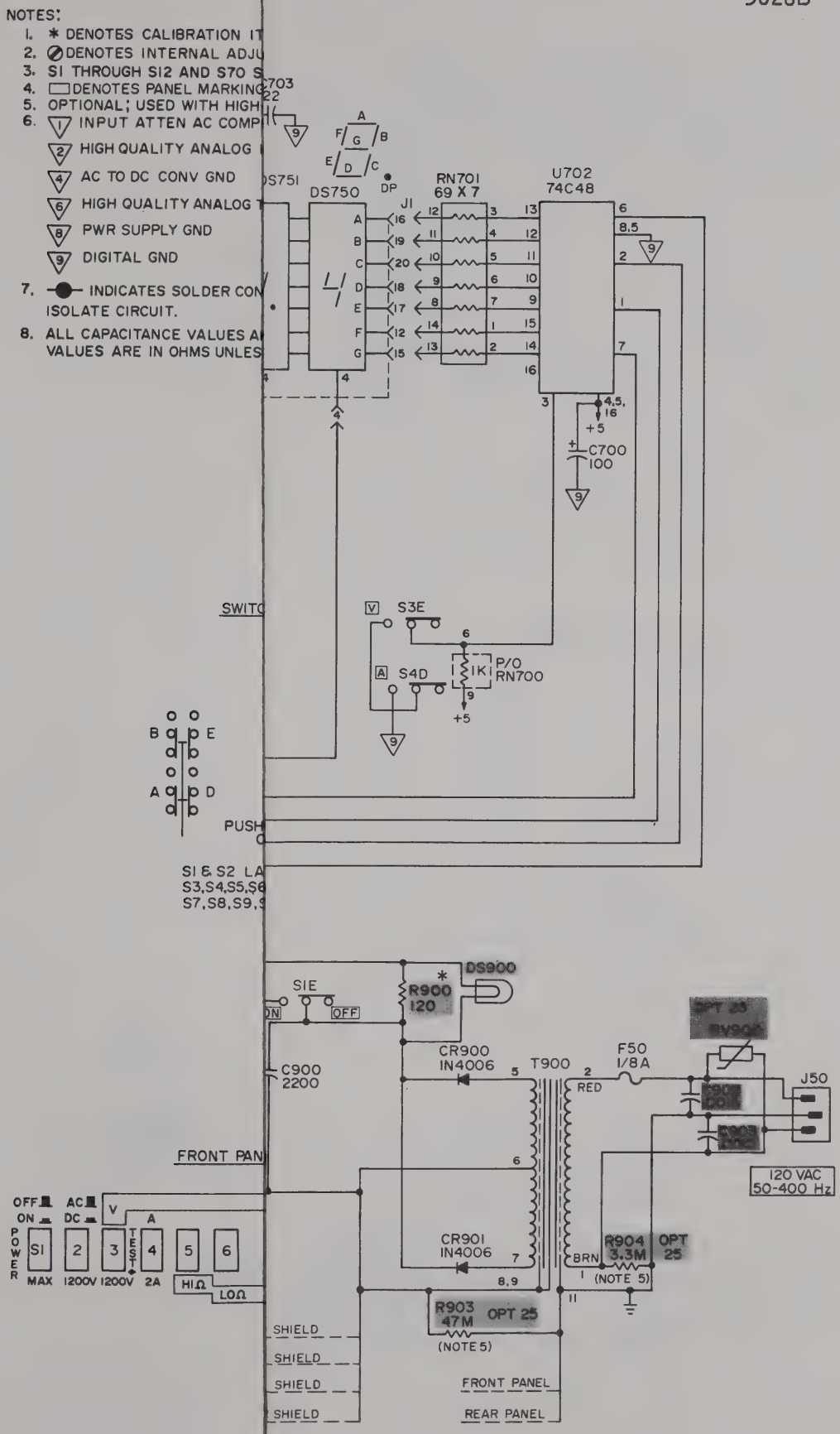


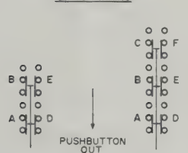
Figure 8-1. Model 3028B, Schematic Diagram
Serial Prefix 050- and below

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
R 506	09100030A	RVC 100.0 K 0.5 WK +-10%	73138	HEL TYP 72PM
R 600	12128620A	RFC 560.0 K 2.0 W 5%	01121	A-B HP
R 601	12128730A	RFC 560.0 K 500.0MW	01121	A-B TYPE E-B
R 602	12010910A	RFC 27.0 K 500.0MW J+- 5%	01121	A-B TYP EB
R 603	12011380A	RFC 1.8 500.0MW K+-10%	01121	A-B TYP EB
R 604	09101460A	RVF 25.0 K 500.0MW TRIMPOT	73138	HELIPOT 72PM
R 605	09101460A	RVF 25.0 K 500.0MW TRIMPOT	73138	HELIPOT 72PM
R 606	09101070A	RVF 200.0 250.0MW K CER	73138	HEL TYPE 72PM-200
R 607	09100020A	RVC 5.0 K 0.5 WK +-10%	73138	HEL TYP 72PM
R 608	09100010A	RVC 500.0 0.5 W K	73138	HEL TYP 72PM
R 609	09100920A	RVF 50.0 K 500.0MW KVERT MT	73138	HELIPOT 72XW 50K
R 801	09101070A	RVF 500.0 0.5W K CER	73138	HEL TYPE 72PM-200
R 904	12129340A	RFC 3.3M 500 MW J+-5%	01121	A-B TYPE EB
RN 200	13100021A	RNW 3028A SHUNT RES,14DIP	50423	BLI
RN 600	13100401A	RNF 3028B 14 PIN DIP 1% RES.	50423	BLI
RN 601	13100421A	RNF 3028B 14 PIN DIP 1,5%RES	50423	BLI
RN 700	*13100961A	RNF 3028B 14 PIN DIP 5% RES.	50423	BLI
RN 701	*13100940A	RNF 69.0 14 PIN DIP 7 RES.	80053	BECKMAN 899-3-R68
RN 800	13100391B	RNF 3028B 8 PIN SIP 120/750	50423	BLI
S 1		SWC 3028B FUNCTION 6 STAT.	50423	BLI
S 2		SWC 3028B FUNCTION 6 STAT.	50423	BLI
S 3	25101441L	SWC 3028B FUNCTION 6 STAT.	50423	BLI
S 4		SWC 3028B FUNCTION 6 STAT.	50423	BLI
S 5		SWC 3028B FUNCTION 6 STAT.	50423	BLI
S 6		SWC 3028B FUNCTION 6 STAT.	50423	BLI
S 7		SWC 3028B RANGE 7 STAT.	50423	BLI
S 8		SWC 3028B RANGE 7 STAT.	50423	BLI
S 9		SWC 3028B RANGE 7 STAT.	50423	BLI
S 10	25101461L	SWC 3028B RANGE 7 STAT.	50423	BLI
S 11		SWC 3028B RANGE 7 STAT.	50423	BLI
S 12		SWC 3028B RANGE 7 STAT.	50423	BLI
S 70		SWC 3028B RANGE 7 STAT.	50423	BLI
T 800	20100291D	TRX 3028A DC/DC CONV.	50423	BLI
T 900	20100581Q	TRX 3028B POWER 120V ONLY	50423	BLI
U 300	24102120A	ICP CA3140S FET OP AMP TO-5	86684	RCA CA3140S TO-5 DU.JN.LN
U 400	24102130A	ICP LM318N FAST OP AMP	27014	NAT.SEMI DUAL IN LIN
U 500	24102120A	ICP CA 3140SFET OP AMP TO-5	86684	RCA CA3140S TO-5 DU.JN.LN
U 600	24102021A	ICP LD11A MODIFIED DVM.03%	50423	
U 700	24100941A	ICP DVM DIGITAL 3 1/2 DIGIT	17856	SILICONIX LD110 MODIFIED
U 701	24101880A	ICP 9667 7 DARLINGTON DRIVE	07263	FAIRCHILD 9667PC
U 702	24101960A	ICP 74C48 7 SEGMENT DRIVE		NATIONAL MM74C48N
U 900	24101530A	ICP UA7805 5V REG.	07263	FAIRCHILD

NOTES:

1. * DENOTES CALIBRATION ITEM, MOST FREQUENT VALUE SHOWN.
2. ⊘ DENOTES INTERNAL ADJUSTMENT.
3. S1 THROUGH S12 AND S70 SHOWN IN OUT POSITION.
4. □ DENOTES PANEL MARKING.
5. OPTIONAL; USED WITH HIGH-VOLTAGE PROBES FOR SAFETY PURPOSES.
6. ▽ INPUT ATTEN AC COMPENSATION GND
   ▽ HIGH QUALITY ANALOG INPUT GND
   ▽ AC TO DC CONV GND
   ▽ HIGH QUALITY ANALOG TO DIGITAL CONV GND
   ▽ PWR SUPPLY GND
   ▽ DIGITAL GND
7. —●— INDICATES SOLDER CONNECTION WHICH MAY BE REMOVED TO ISOLATE CIRCUIT.
8. ALL CAPACITANCE VALUES ARE IN MICROFARADS AND ALL RESISTANCE VALUES ARE IN OHMS UNLESS NOTED OTHERWISE.

SWITCH WIRING



S1 & S2 LATCHED INDIVIDUALLY
S3,S4,S5,S6 LATCH 1 OF 4
S7,S8,S9,S10,S11,S12,S70 LATCH 1 OF 7

FRONT PANEL SWITCH MARKING

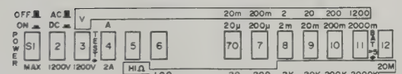


Figure 8-1. Model 3028B, Schematic Diagram
Serial Prefix 050- and below

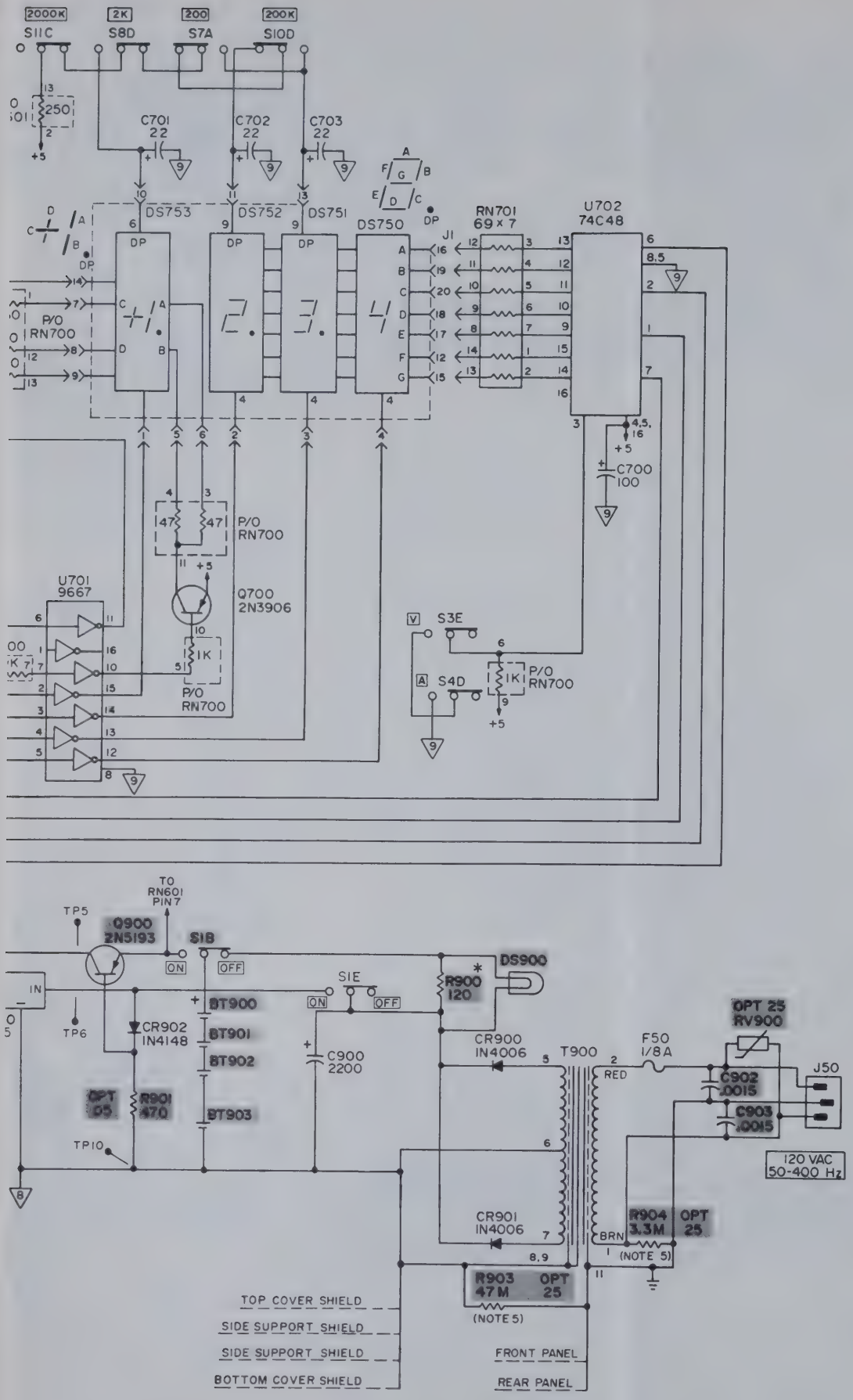
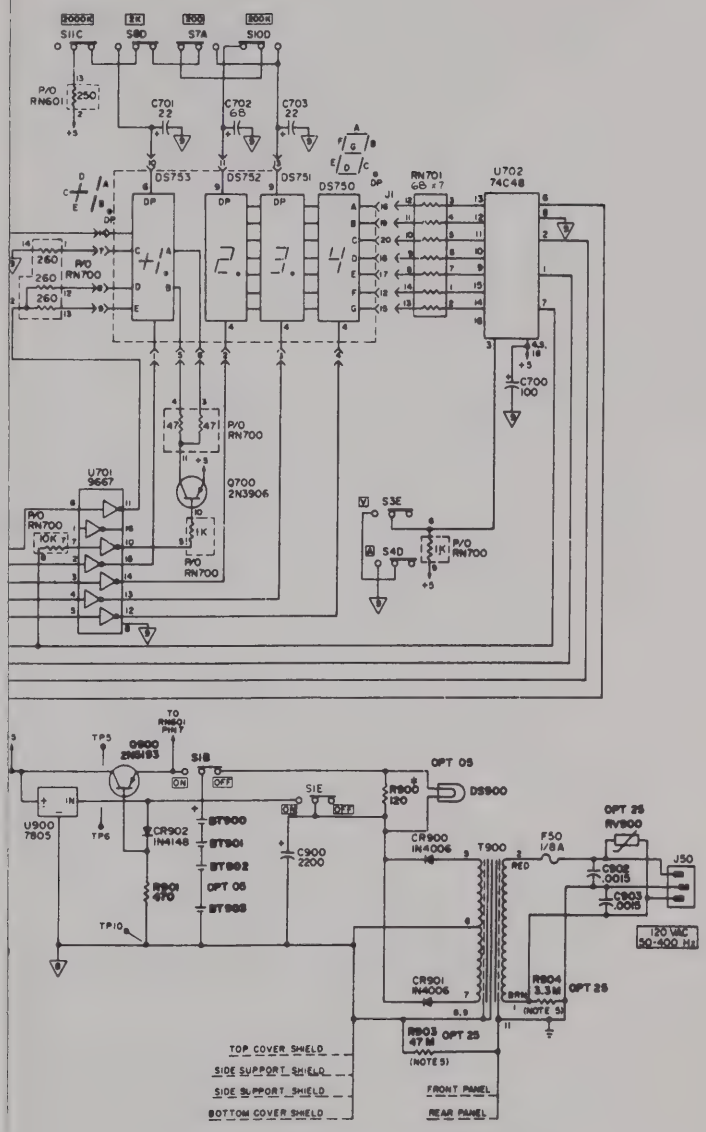


Figure 8-2. Model 3028B, Option 24, Schematic Diagram, Serial Prefix 050- and below



9. THIS CONNECTION NORMALLY CLOSED (N/C). FOR OPTION 25 THIS CONNECTION IS OPEN (N/O). L901 BECOMES A WIRE JUMPER WHEN OPTION 25 IS NOT INSTALLED.

Figure 8-3. Model 3028B, Option 24H, Schematic Diagram, Serial Prefix 050- and below

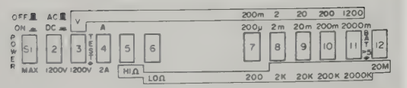
NOTES:

1. * DENOTES CALIBRATION ITEM. MOST FREQUENT VALUE SHOWN.
2. ⊘ DENOTES INTERNAL ADJUSTMENT.
3. S1 THROUGH S12 AND S70 SHOWN IN OUT POSITION.
4. □ DENOTES PANEL MARKING.
5. OPTIONAL; USED WITH HIGH-VOLTAGE PROBES FOR SAFETY PURPOSES.
6. ▽ INPUT ATTEN AC COMPENSATION GND
   - ▽2 HIGH QUALITY ANALOG INPUT GND
   - ▽4 AC TO DC CONV GND
   - ▽6 HIGH QUALITY ANALOG TO DIGITAL CONV GND
   - ▽8 PWR SUPPLY GND
   - ▽9 DIGITAL GND
7. —● INDICATES SOLDER CONNECTION WHICH MAY BE REMOVED TO ISOLATE CIRCUIT.
8. ALL CAPACITANCE VALUES ARE IN MICROFARADS AND ALL RESISTANCE VALUES ARE IN OHMS UNLESS NOTED OTHERWISE.

SWITCH WIRING

S1 & S2 LATCHED INDIVIDUALLY
S3,S4,S5,S6 LATCH 1 OF 4
S7,S8,S9,S10,S11,S12 LATCH 1 OF 6

FRONT PANEL SWITCH MARKING



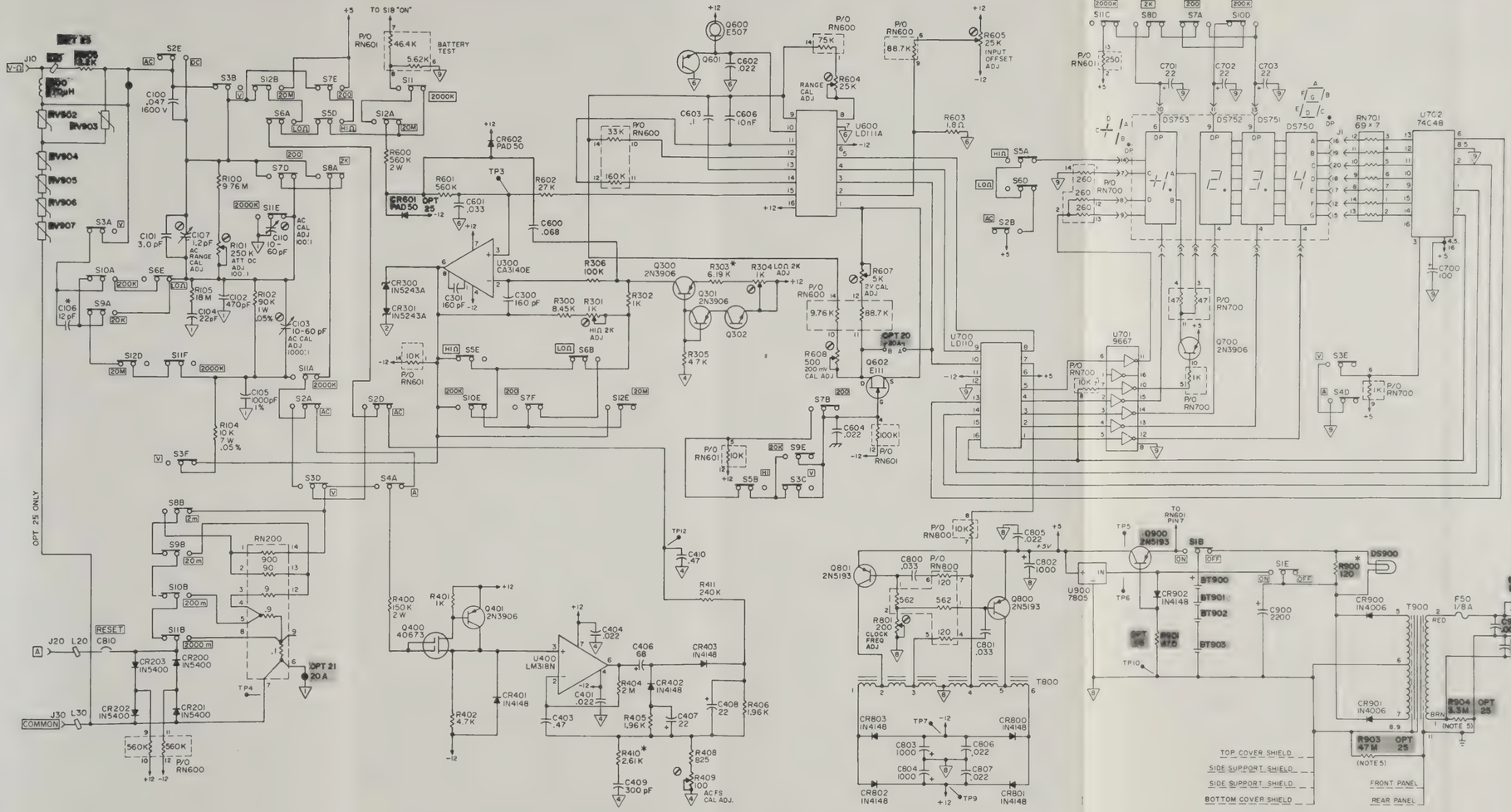
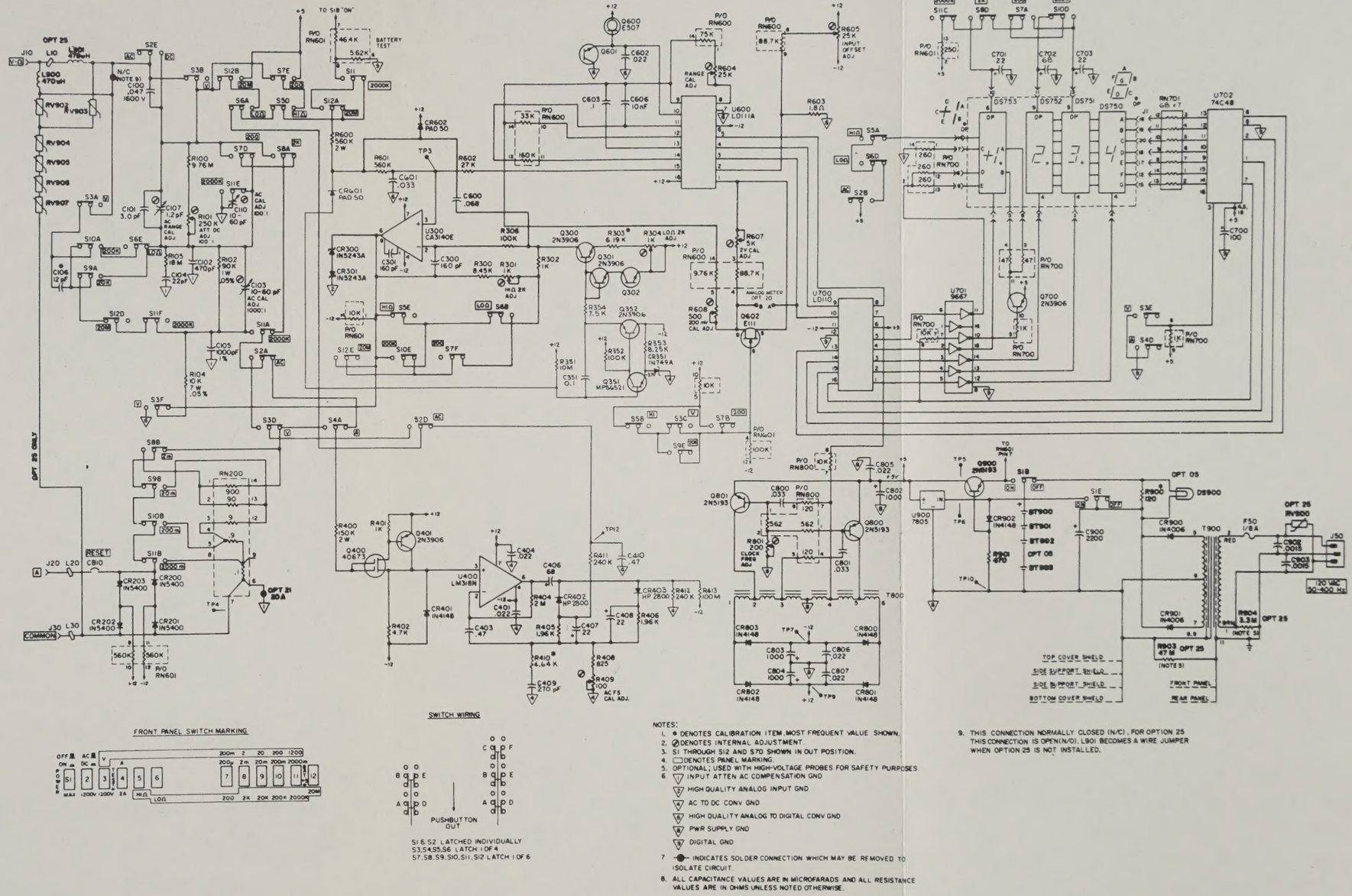


Figure 8-2. Model 3028B, Option 24, Schematic Diagram, Serial Prefix 050- and below



NOTES:
1. ✱ DENOTES CALIBRATION ITEM. MOST FREQUENT VALUE SHOWN.
2. ⊘ DENOTES INTERNAL ADJUSTMENT.
3. S1 THROUGH S12 AND S70 SHOWN IN OUT POSITION.
4. ▭ DENOTES PANEL MARKING.
5. OPTIONAL; USED WITH HIGH-VOLTAGE PROBES FOR SAFETY PURPOSES.
6. ▽ INPUT ATTEN AC COMPENSATION GND
   - ▽ HIGH QUALITY ANALOG INPUT GND
   - ▽ AC TO DC CONV GND
   - ▽ HIGH QUALITY ANALOG TO DIGITAL CONV GND
   - ▽ PWR SUPPLY GND
   - ▽ DIGITAL GND
7. —●— INDICATES SOLDER CONNECTION WHICH MAY BE REMOVED TO ISOLATE CIRCUIT.
8. ALL CAPACITANCE VALUES ARE IN MICROFARADS AND ALL RESISTANCE VALUES ARE IN OHMS UNLESS NOTED OTHERWISE.
9. THIS CONNECTION NORMALLY CLOSED (N/C). FOR OPTION 25 THIS CONNECTION IS OPEN(N/O). L901 BECOMES A WIRE JUMPER WHEN OPTION 25 IS NOT INSTALLED.

Figure 8-3. Model 3028B, Option 24H, Schematic Diagram, Serial Prefix 050- and below

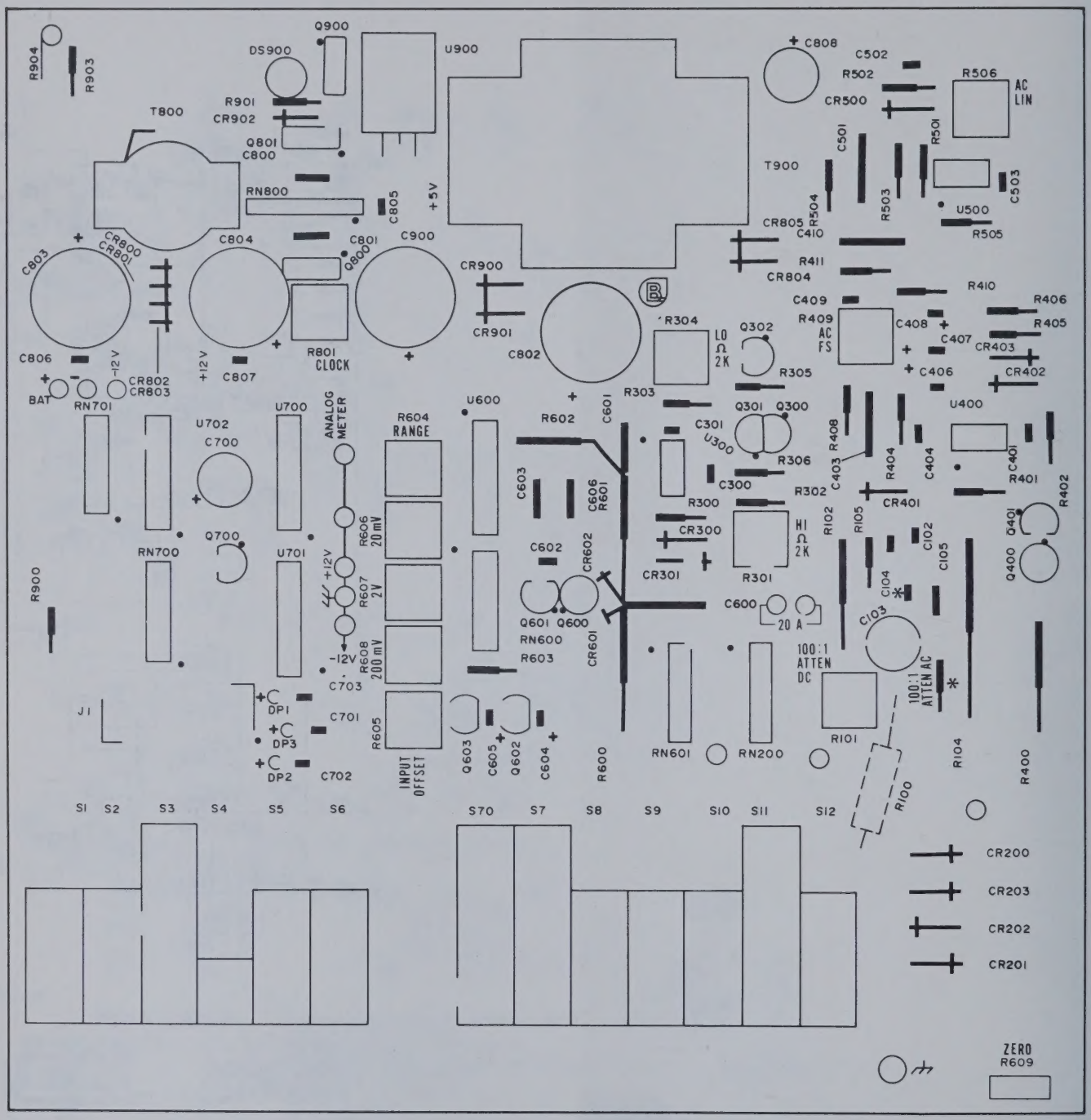


Figure 8-4. Model 3028B, Parts Location Diagram

Ballantine Laboratories, Inc.
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